PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES
Volume 5 OCTOBER 15, 1919 Number 10

*SOME PROBLEMS OF SIDEREAL ASTRONOMY**

By Henry Norris Russell

Bulletin of the National Research Council, Number 2

Communicated to the National Academy of Sciences, June 17, 1917

The main object of astronomy, as of all science, is not the collection of facts, but the development, on the basis of collected facts, of satisfactory theories regarding the nature, mutual relations, and probable history and evolution of the objects of study. Before the existing data appear sufficient to justify the attempt to form such a general theory, two policies of investigation may be followed: (1) to collect masses of information, as accurate and extensive as possible, by well tested routine methods, and leave it to the insight of some fortunate and future investigator to derive from the accumulated facts the information which they contain regarding the general problems of the science; (2) to keep these greater problems continually in mind, and to plan the program of observation in such a way as to secure as soon as practicable data which bear directly upon definite phases of these problems.

Much valuable and self-sacrificing work has been done by astronomers who adopted the former policy. In the opinion of many investigators, however, the progress of astronomy would be hastened if fuller consideration were given to the second method of attack, especially with a view to the widest possible coöperation between different observers and institutions.

In the hope that the committees of the National Research Council may be of service in furthering such coöperation, and at the request of the Chairman of the Council, the following survey has been attempted of the general problems of sidereal astronomy, and of investigations which at present promise advances toward their solution.

* This is issued as the first of a series of research surveys prepared under the auspices of the National Research Council.

I. The Individual Stars.—Existing methods of investigation have already put at our disposal a great mass of information regarding the physical characteristics of the stars—mass, density, luminosity, color, spectrum, temperature, and so on. The central problem of stellar astronomy may be formulated as follows: From the existing data, and from all further data which may be secured by methods new or old, to deduce a theory of stellar evolution, that is, of the changes in the temperature, density, brightness, spectrum, and other observable characteristics of a star with the progress of time, and of the dependence of these changes upon those factors which are invariant for a given system, such as mass, angular momentum and chemical composition. Such a theory must satisfactorily represent the observed properties of the general run of the stars, and the relative abundance of the different types, and must be capable of extension so as to account for the exceptions to the usual rules.

Among the subsidiary problems whose solution is bound up with that of the main problem are (*a*) that of the evolution of binary systems, whether by fission, tidal action, or otherwise; (*b*) that of the causes and mechanism of variable brightness among the stars; (*c*) that of the source of the energy which the stars radiate into space in such enormous amounts.

These problems of stellar astronomy are mainly physical in character, though some phases, such as (*a*) are mainly dynamical.

II. The Galactic System.—The great majority, if not all, of the visible stars appear to belong to an assemblage limited in space, either by regions nearly void of stars, or by absorbing material which conceals whatever may be immersed in it. Within this galactic system we may investigate the distribution of the stars in space, and its variation for stars of different spectral type, absolute magnitude, etc., the motions of the stars (including the Sun), and the phenomena of preferential motion ('star-streaming') in certain directions, and the dependence of these motions upon spectral type, absolute magnitude, etc.; and the association of the stars into sub-groups, or clusters, and the motions of these clusters.

All these studies lead up to a single ultimate problem, which may be defined as the representation of the present positions and motions of the stars as a stage in the history of a dynamical system (whether in a steady state or not) and the deduction of the presumable history of the system in the past and the future. Among the subsidiary problems connected with this are (*a*) the existence, character, distribution and gravitational influence of possible dark or absorbing matter in space; (*b*) the

relation between the age or evolutionary stage of a star and its position and motion within the galactic systems. The latter connects the problems of stellar and galactic evolution in such a way that any notable advance in the solution of one is likely to be of aid in that of the other, while an unfounded assumption regarding either will probably confuse the discussion of both.

III. Clusters and Nebulae.—So little has been known of these objects until very recently that the problems which they present can hardly yet be coördinated into a single statement. Among the most obvious are:

(1) The relations of clusters and nebulae to the galactic system. It now appears probable that the galactic system is very much larger than was supposed a few years ago, and that not only the irregular clusters, and the gaseous nebulae, both planetary and extended, but also the globular clusters, and probably the Magellanic Clouds, lie within its confines. But the relations of the spiral nebulae are still uncertain.

(2) Motions and dynamical relations within clusters, especially globular clusters, and explanation of the law of distribution of stars in such clusters.

(3) Nature of the gaseous nebulae, especially of 'nebulium,' and cause of their luminosity. Internal motions in gaseous nebulae.

(4) Nature of spiral nebulae, and explanation of the rapid motions of their parts.

In all these cases a persistent attempt should be made to account for the observed phenomena by means of the known properties of matter and forces of nature, and the existence of unknown forces should be postulated only if there is apparently no escape from the necessity of doing so.

It may now be profitable to survey rapidly the different fields of astronomical investigation, and consider the bearing of various researches —some now under way, some practicable at present, and others desirable if means for effecting them can be devised—upon these general problems.

1. Spectra.—It seems to be increasingly clear that the master-key to these problems, so far as they have yet been formulated, lies in the investigation of the spectra of the stars and other bodies, and the correlation of their other characteristics with the spectra. Fortunately, the spectra are among the few characteristics which can be investigated independently of any knowledge of the distances of the various bodies,—and, indeed, of the distances themselves, except for the limitation arising from the faintness of most of the remoter objects.

(*a*) Two fundamental facts appear upon the study of the lines of stellar spectra. The first is that almost all of the thousands of lines which have been observed are identifiable as those of known elements, and can be reproduced under conditions which can be realized in terrestrial laboratories. The few outstanding exceptions are yielding year by year. The recent identification of the G band in the solar spectrum as due to hydrocarbons,[1] and of the bands of ammonia[2] and water-vapor[3] in the ultra-violet, leaves very few 'unknown' solar lines of any importance. Nor are there any of great account in stellar spectra, except in stars of the fourth type (Class N) and in the Wolf-Rayet and 'early' helium stars.

So many of the lines in the latter have recently been found to be identical with those given in the laboratory by familiar elements (such as hydrogen, oxygen, carbon, and helium), under unusually intense electrical excitation[4] that there is good reason to hope that further researches in this direction may account for those which still remain, and even solve the long-standing riddle of the origin of the characteristic nebular lines (which are associated with the Wolf-Rayet lines in the nuclei of planetary nebulae and in new stars at certain stages). The spectrum of the solar corona, however, still remains an isolated problem.

(*b*) The second great fact is that the vast majority of stellar spectra fall into a single, continuous, linear sequence, which forms the basis of the Harvard system of classification, now generally adopted. Almost all the spectra which did not obviously belong to this sequence have been brought into connection with it by the recent work of Wright,[5] connecting the gaseous nebulae with the Wolf-Rayet stars at the head of the series, and that of Curtiss and Rufus,[6] which shows that the small but definite classes R and N form a sort of side-chain, branching from the main sequence near the other end, at class G (or perhaps K). Miss Cannon's experience[7] in classifying over 200,000 spectra shows that the objects that do not fall into the sequence, thus extended, are almost vanishingly rare.

The general characteristics of this sequence are now well established, and the types which were selected, by a sort of survival of the fittest, in the evolution of the Harvard classification prove to have been surprisingly well distributed along the series. With the aid of the quantitative methods of classification developed by Adams and Kohlschütter,[8] the precise classification of any spectrum of which a good photograph with suitable dispersion is available should be an easy

matter, even in the interval between G and K5, where the differences between consecutive types are least prominent. The publication of a detailed descriptive 'key' with good reproductions of photographs of spectra of each successive class would however be a great boon to isolated workers.

Of much greater importance is the devising of some method for photographing the spectra of stars fainter than the tenth magnitude—which are now about at the limit of accessibility. Long exposures with the objective prism are greatly embarrassed by difficulties in guiding, but the problem is doubtless soluble in some way, and ought to be solved.

(*c*) There is now good reason to believe that the differences between the main classes of spectra arise from differences in the effective surface temperatures of the stars, and that differences in their other physical characteristics play only a minor rôle in the spectra, but reveal themselves in differences in detail, formerly described as 'peculiarities' when they were noticed at all. The investigation of these finer differences is to-day the most promising field in stellar spectroscopy.

What valuable results may be obtained was shown by Hertzsprung's[9] work on Miss Maury's 'c-stars' (with unusually sharp spectral lines) which prove to be of greater real brightness than any other class of stars so far known; and later, and still more remarkably, by Adams' and Kohlschütter's[10] discovery that the absolute magnitudes of stars (of the 'later' spectral classes, at least) can be predicted with surprising accuracy from the relative intensity of a few pairs of lines in their spectra. The data for stars of great luminosity are still scanty, but should be easily obtainable, using the hundreds of spectrograms now available at the great observatories, and determining the mean absolute magnitude of groups of stars, which the spectroscopic method indicates as being of similar brightness, by means of their parallactic motions. When this has been done, our knowledge of the distribution of the naked-eye stars in space will be very greatly advanced.

The careful comparison of the spectra of pairs of stars otherwise similar, but known to differ in other characteristics than absolute magnitude, may yield results of importance. Many recognizable spectral 'peculiarities' too, such as the diffuseness or sharpness of the lines, the presence of bright lines, the abnormal strength or weakness of certain lines, etc., have as yet been very incompletely studied, especially as regards their relation to other characteristics of the stars. For example, it should be possible to distinguish between widening of spectral lines due to a star's rotation, (which would affect all lines alike), and

widening due to physical conditions in its atmosphere (which are likely to affect some lines more than others).

(*d*) Another promising field is found among the reddest stars. Curtiss makes the very interesting suggestion that the division of the spectral series into the branches G–K–M and G–R–N (or perhaps K–R–N) may be due to differences of chemical composition[11]—since it is known that the surface temperatures of these stars are low enough to permit the formation of chemical compounds. If this is true, the strength of the characteristic bands of titanium oxide or of carbon should depend upon the relative proportions of these elements, and show little correlation with the color index, or the extension of the spectrum in the violet, which depend primarily on the temperatures. There is already considerable evidence that this is actually the case, and it may be remarked that the star Epsilon Geminorum, which is of spectral class G5 has a color index (+1.52) almost equal to that of Classes M or R.[12] This star may be in the situation anticipated by Curtiss, in which an exact chemical equilibrium between carbon and titanium oxide suppresses the bands of both.

Photography of the spectra of bright stars in the red, and even the near infra-red, is now practicable, and Merrill[13] has already obtained results of great interest and promise. Investigation of the spectra of the brightest stars with high dispersion is also profitable, as is shown by the work of Adams[14] upon the pressures which probably prevail in the atmospheres of Sirius, Procyon, and Arcturus. Fortunately, the stars brighter than the second magnitude afford examples both of giant and dwarf stars of almost every spectral class.

2. (*a*) Almost equal in importance to the line absorption in stellar spectra is *the distribution of intensity in the continuous background.* The most complete and satisfactory method of studying this would be the direct measurement of the energy carried by different wave-lengths, but this has not yet been proved practicable. A first step has however been taken by Coblentz,[15] who has not only measured the total energy radiation of more than a hundred stars, but in some cases the percentage transmitted by a water cell, thus providing our first knowledge of stellar radiation in the infra-red. With the great reflectors just completed, the determination of spectral energy curves for the brightest stars may be possible.

The distribution of energy in the luminous region of the spectrum is however readily determinable. For the brighter stars, spectro-photometric methods can be employed, as in the visual work of Wilsing

and Scheiner,[16] and the photographic investigations of Rosenberg.[17] Fainter stars, down to the sixteenth magnitude, at least, can be reached by the determination of *color indices*.

(*b*) In order that these color indices may be capable of full utilization, it is necessary, first, that trustworthy and homogeneous scales of visual, photographic and photovisual magnitudes be established over the whole range of about 47 magnitudes from the Sun to the faintest observable stars. This problem, which is fundamental in all stellar photometry, is already well advanced toward solution. But in the second place, it is necessary that the physical meaning of the units of magnitude should be precisely known; that is, that the 'luminosity curve' which expresses the relative sensitiveness of the photometric receiver for equal energy of different wave-lengths should be exactly determined. And, above all, it is essential that this luminosity curve should be independent of the brightness of the stars under observation. These last two conditions are at present very imperfectly satisfied, if at all. Very little is known about the luminosity curves of the standard plates and apparatus used in the determination of photographic and photovisual magnitudes, and nothing at all about the luminosity curves of the eyes of the 'standard observers' at different observatories,—except that they must be very different under the conditions prevailing at Harvard and at Potsdam.[18] It is certain that the Purkinje effect alters the form of the visual luminosity curve as the brightness of the illumination varies, probable that this affects the visual comparison of the brightness of stars of widely different magnitudes, and uncertain whether, and to how great an extent, similar photographic influences exist.[19]

The direct determination of the luminosity curves for the principal instruments and methods employed in the determination of photographic and photovisual magnitudes would be neither difficult nor laborious. For visual observations it can be derived indirectly, if direct measures prove difficult. To make these investigations at once is urgently desirable, for the present bases of the scales of stellar magnitude are not permanent. The photographic and photovisual scales depend on the properties of present commercial types of rapid plates, which may not be manufactured a few years hence if improvements are devised; and the visual scales are based on the characteristics of the eyes of observers some of whom have already retired from active work.

Such an investigation would also establish a connection between the scales of stellar magnitude and the physical units of measurement of light in the laboratory (which are now defined in terms of a definite

luminosity curve), and would enable us to express our stellar photometric data in absolute units.

It is also desirable that methods for measuring the brightness of the stars with red and ultra-violet light should be developed, with careful determination of the luminosity curve in each case, and of the color equation which (for normal stars) makes it possible to reduce color-indices obtained on any of these systems to a standard scale.

The determination of the colors of faint stars by other methods affords a promising field, as is shown by the success of the method of effective wave-lengths,[20] and of that of exposure ratios,[21] recently developed at Mount Wilson.

Such a determination of exact scales of magnitude and color index is evidently a necessary condition for the full utilization of the great mass of material which is in process of collection concerning the numbers of stars of different magnitudes, their concentration towards the Galaxy, etc.

(*c*) The statistical investigation of the relations between color index and spectral type, and between both and absolute magnitude, have already opened up possibilities of estimating the distances of stars far too remote to be reached in any other way. Such investigations should be extended, with special reference to stars of great and small absolute brightness, and to those having peculiar spectra.

Closely connected with this is the question of possible selective absorption of light in space. Shapley's results,[22] and the theoretical work of L. V. King,[23] appear to negative the existence of any general absorption of this sort. But local selective absorption may occur, and it would be well worth while to study intensively the color indices and spectra of stars in regions where the existence of absorbing matter is suspected, such as Barnard's dark lanes in Scorpius. It is interesting in this connection to note that the three most abnormally yellow stars of Class B (ζ, o and ξ Persei)[24] lie within 5° of one another, in a region full of diffuse nebulosity.[25] A survey of the stars in this region for color-index and spectral type would be well worth while.

(*d*) Another interesting problem is presented by the extreme infrequency of very red stars. Color-indices up to about +1.8 on the Harvard scale are fairly common; but greater values are very unusual, and are practically confined to the 'side chain' which includes Class N. In this subsidiary sequence the color-indices increase to about +4, as might be expected as a result of decreasing temperature; but in the main series, ending in Class M, this does not happen. Are all the stars of Class M of about the same temperature, or is an increase of redness in Classes Mb and Mc masked by increasing absorption in the

red end of the spectrum? There are certainly very heavy absorption bands in the red in these spectra; and further evidence in favor of this hypothesis is found in Coblentz's measures of Alpha Herculis,[26] which show this star, of Class Mc, radiates far more heat in proportion to its light than do stars of Class Ma, and also in Hertzsprung's[27] observation that the very faint dwarf stars of Class Mb are not nearly as red as their small luminosity, and probable low surface brightness, would lead one to suppose. A careful study of the color indices, and, if possible, of the spectral energy curves, of the stars of Classes Ma, Mb, and Mc is much to be desired. The extraordinarily red stars S Cephei[28] and +43°53,[29] which have color indices exceeding five magnitudes, should be included in such a study.

3. One other stellar characteristic which may be investigated without knowledge of distance is *variability of brightness*. If we really understood the causes of stellar variability, we should probably have advanced a long way towards the solution of the whole problem of stellar evolution, if not have solved it completely. But, in spite of the great number of variable stars, the variety of the phenomena which they represent, and the accuracy with which they can now be observed, the humiliating admission must be made that no even tolerably satisfactory theory of the causes of the variation exists, except for the eclipsing variables, and in this case it is based on the proposition that, except for the accident of eclipse, the components are not variable at all!

Successful attack upon the problem of intrinsic stellar variation will probably demand the correlation of all the data that can be brought together from every accessible source. In the case of regular variables, precise light curves are of importance, and many stars still await investigation,—some of them visible to the naked eye, and long known to be variable. The new photometric methods of precision—especially the photoelectric cell—have opened a wide field in the study of bright stars with small variation, in which important results have already been obtained,—notably by Stebbins[30] and Guthnick,[31]—and more may be anticipated.

(*a*) Former suspicions of changes in form of the light curves appear to have been unfounded in the case of eclipsing variables; but similar changes are believed with good reason to exist among Cepheid variables.[32] To prove their reality—still more to discover their laws—demands very precise observations, preferably by two or more observers at different places and the same time.

(*b*) Changes in color, as well as in brightness, appear to be the general —perhaps the invariable, rule among eclipsing variables, and especially

among Cepheids—the star being always redder at minimum than at maximum. More recent observations show that changes in the spectrum go hand in hand with the others.

In the case of eclipsing variables, these changes arise from a difference in spectral type between the components, and it is found that stars separated by an interval less than their own diameters, and therefore very probably of the same origin and age, may have spectra differing as widely as those of Sirius and Arcturus.[33] Observations of such systems, when the eclipse is total, provide the only direct method at present existing for studying the relations between spectral type, color index, surface brightness, and density, which are of fundamental importance. The determination of the spectral type of the fainter components of such systems, though often very difficult, on account of their extreme faintness, deserves special effort.

(*c*) The concomitant variations in brightness, color, and spectrum, which Shapley[34] has shown to occur in every Cepheid variable that has been properly investigated, indicate very strongly that the proximate cause of the changes in all three is a periodic variation in the surface temperature of the stars. Shapley's suggestion[35] that these differences in temperature arise from some sort of internal changes, perhaps of the nature of periodic oscillations in the radius, density, temperature, etc., appears to be the best which has been yet made; but there are still grave difficulties in explaining how such pulsations should in all cases produce the very distinctive form of the light curve, with its rapid rise and slow fall, and still greater trouble in accounting for the variations in radial velocity, which show so remarkable a relation, both in amplitude and phase, to those in light. It is in fact still doubtful whether these stars are really binary systems or not. Intensive studies of a number of these variables, including the greatest practicable variety of representative cases, would be well worth while.

(*d*) Still less is known concerning the very numerous variables of long period, and the roughly periodic and irregular variables. In the observation of their changes in brightness, amateur observers may obtain results of much value, and, under the admirable coöperative schemes organized by the American and British Associations of Variable Star Observers, they are at present furnishing a great mass of valuable information. Very little is known regarding changes in the spectra of long-period variables, except that they often exist,[36] especially as regards the bright hydrogen lines which are usually present at maximum. Observations of the color indices of these variables are also much to be desired. Certain peculiar variables, such as R Coronae and SS Cygni,

are typical of small but definite groups, whose variation, though quite distinctive, is entirely unpredictable. The spectra of the stars of the first of these groups are similar to one another, and unlike anything else.[36] Those of the second group are also peculiar, and appear to be variable.[36] Both present problems as alluring as they are difficult. The spectra of other peculiar variables also deserve investigation.

(*e*) New stars are usually pretty fully observed while they remain bright, but work remains to be done in following at shorter intervals the changes during their later stages. The recent work of Adams and Pease[37] indicates that they settle down into Wolf-Rayet stars; but, according to Miss Cannon,[38] the spectrum of the Nova in Corona, fifty years after its outburst, is now of class K. No one seems yet to have followed up Hertzsprung's interesting suggestion[39] that stars of very small absolute luminosity should be investigated for variability. Abundant material for a photographic study must exist in the Harvard collection.

4. Knowledge of the *distances* of the stars is indispensable in the solution of many problems. The nearer ones, to a distance of thirty parsecs or so, are now accessible to direct measures of *parallax*, and great activity prevails in photographic observation for this purpose, in accordance with a wide and well-considered plan of coöperation.

In my opinion, however, the greatest need in parallax work at present is the investigation and elimination of the systematic errors which are still present in the best work, as is shown by the too frequent appearance of large discordances—sometimes amounting to more than $0''.05$—between the results of different observers, although the probable errors derived from the internal agreement of each observer's plates are of the order of $\pm 0''.01$. The intercomparison of the results of various observers for the same stars is hardly a sufficient test for the absence of systematic error, especially as all are using nearly the same method of observation. The only secure control is afforded by observing stars whose parallaxes can be predicted, from other considerations, with greater accuracy than they can be observed. This demands prediction with a probable error not exceeding $\pm 0''.005$. Fortunately, several groups of stars exist for which such prediction is possible. The most prominent of these consists of those stars of spectrum B which are between 60° and 120° from the solar apex. If the parallaxes of these stars are computed on the assumption that their individual proper motions are entirely due to the solar motion, the resulting errors will correspond to a probable error of less than one-third of the parallaxes themselves—that is, to about $\pm 0''.002$. The

stars of Kapteyn's Scorpius-Centaurus group[40] would be ideal objects, if they were not too far south.

For fainter stars, eclipsing and Cepheid variables are available. Of the 90 eclipsing variables whose parallaxes were estimated by Russell and Shapley,[41] 69 are fainter than the eighth magnitude, and the mean parallax of these is 0".002, while only ten per cent exceed 0".004. For the Cepheids of similar brightness, the parallaxes estimated by Hertzsprung and Shapley[42] are even smaller.

When once the systematic errors have been tracked to their source and eliminated, an extensive program of observation can be undertaken with security. Much duplication of observations is desirable, for it is obviously better that the parallax of a star should be determined from the mean of three or four short series of as many different observatories than by a series with a single instrument, however long and elaborate. Certain objects for which especially accurate parallaxes are desirable should be observed at as many places as possible. Examples are binary stars, stars differing in absolute magnitude from the bulk of those of the same spectral class, or from the values predicted by the spectroscopic method, stars with exceptionally rapid motions in space, planetary nebulae, etc. Attempts to determine by direct observation the mean difference in parallax between classes of stars with small parallaxes (for example, those of the third and fourth magnitudes, taken as a whole) should, in my judgment, be deferred until the systematic errors have been thoroughly cleaned out.

5. Knowledge of parallax leads at once to that of *absolute magnitude*, which, in the interest and importance of its systematic relations to other characteristics of the stars, stands second only to spectral type.

(*a*) The relations between the two afford a very interesting study, which has led Hertzsprung[43] and Russell[44] to the recognition of the two series of 'giant' and 'dwarf' stars, coincident in class B, but gradually drawing apart among the redder stars until, as Adams' spectroscopic results have recently confirmed,[45] they are completely and widely separated in class M. If Russell's views are correct, the existence of these two series is the key to the problem of stellar evolution. In any case, their existence must be accounted for, and will be of importance in testing any theory. The securing of additional data, especially regarding the absolute magnitudes of individual giant stars, is much to be desired. It is of importance to determine not only the mean absolute magnitude of the giant and dwarf stars of each spectral class (whenever the two are separated) but the dispersion of the individual values about the mean. Only when the latter is known can the results

of statistical investigations be cleared from the effects of the egregious observational preference for the brighter and remoter stars.

(*b*) Kapteyn[46] has obtained fairly good values of the dispersion among the various divisions of Class B, and provisional values for Class A; and Russell[47] has given rough estimates for the dwarf stars, and a still rougher one for the giants of Class M: but further work is greatly needed. Adams' spectroscopic method offers an easy solution of the problem, as soon as his present provisional scale of absolute magnitudes for the giant stars has been revised with the aid of studies of the parallactic and peculiar motions of groups of stars whose spectra indicate that they are similar in real brightness. Strömberg[48] has already shown in this way that Adams' mean absolute magnitude for all the giant stars, taken together, is substantially correct; but there is evidence that the provisional estimates for the very brightest stars (such as the Cepheid variables) make them considerably too faint.[49]

(*c*) The existing evidence indicates that the majority of the stars of any given spectral class are confined within surprisingly narrow limits of absolute magnitude (provided that the giants and dwarfs can be treated separately). But there are exceptions of great interest. For example, Kapteyn[50] has shown that β Orionis is some eight magnitudes brighter than the average for its class (B8); and the faint companions of Sirius[51] and o^2 Eridani[52] have spectra of class A, although they are at least eight magnitudes fainter than normal stars of this class. Exceptional brightness is probably explicable by unusual size or mass; but the two exceptionally faint stars (which are known to be of normal mass for stars of their brightness) present a real puzzle. Something about the physical conditions in these stars must be very unusual, and they should be studied with the greatest attainable detail. Other such objects may be found among the faint stars of large proper motion.[95]

6. Beyond the limit of direct measures of parallax, our main reliance must be placed on *proper motions*, which are of fundamental importance in the study of the galactic system.

The brighter stars have already been cared for by Boss, and those down to magnitude 7.5 are under discussion. The fainter stars can best be investigated by photography, carrying the work to objects as faint as can be reached with large instruments, in accordance with Kapteyn's 'Plan of Selected Areas' or some equivalent. For this purpose, it is essential to have a set of reference stars, distributed uniformly over the sky, and of suitable brightness to serve as photographic standards, and to make the observations strictly differential with respect to these, using them not merely as reference points for position when reducing a

single plate, but as reference points for proper motion when comparing two plates of different epochs. The observations of these reference stars must at present be made with meridian circles; but the proposed methods for determination of absolute positions of the stars by photography deserve careful study and trial.

Pending the completion of such a program, the investigation of the proper motions of faint 'optical' companions of bright stars, such as has been made by Comstock,[53] furnishes our best source of information concerning the proper motions of faint stars, but is complicated by systematic errors in the early measures. A survey of the whole heavens for stars of large proper motion is very desirable. In this case it is legitimate to treat the general 'background' of stars as at rest, and the observations can be very rapidly made, with the blink microscope or similar appliances. Early plates are probably already available for almost, if not quite, the whole of the heavens. Such an investigation is likely to yield important information concerning the stars of very small absolute luminosity—as is shown by Barnard's[54] and Innes's[55] recent remarkable discoveries—and should be extended to the faintest accessible stars.

Comparison of measures of plates taken at different epochs (still treating the bulk of the stars as fixed) will yield much information about proper motions of moderate size. This has already been done on an extensive scale with plates of the Astrographic Catalogue.

Special investigations should be made to determine at an early date the proper motions of all stars belonging to certain interesting classes for which early determinations of position are available—for example, binaries, variables, and stars having peculiar spectra.

7. The study of the *radial velocities* of the stars is intimately associated with that of the proper motions. The determination of radial velocities with the slit spectroscope has been brought to a high degree of perfection, but the separate investigation of each one of the many thousands of stars which are now accessible would involve an enormous amount of labor. The development of some method by which radial velocities could be determined *en masse* with the objective prism would be a great boon. If some absorbing medium giving sharp and well distributed lines in the blue and violet could be found, the problem would become simple; and other solutions are doubtless possible.

It is also desirable that some method be devised for obtaining, at least approximately, the radial velocities of stars possessing spectra with very diffuse lines. At the present time, no radial velocities have been published for some of the very brightest stars, on this account.

In extending the list of observed radial velocities, much advantage has been gained by a policy of selective observation of classes of stars of special interest—such as stars of unusually large and small proper motion, absolute magnitude, and the like, variable stars, and stars of the rarer spectral types. A similar investigation of double stars showing evidence of physical connection would be worth while.

8. Statistical discussions of the motions of the stars and of the Sun, and their relation to spectral type, etc., offer an extensive and very intricate field. Among the matters demanding further investigation may be mentioned the reason for the differences in the direction and velocity of the solar motion derived from stars of different spectral types, and from proper motions and radial velocities separately; the origin of the constant term in radial velocities (Campbell's K term); the existence of tendencies toward common motion among the stars in particular regions of the sky; the dependence of the mean peculiar velocities of the stars upon spectral type and absolute magnitude, and the real cause of this dependence (possibly a correlation between large velocity and small mass); the true nature of preferential motion, and whether it really gives evidence of the existence of two physically different 'streams;' the dependence of preferential motion upon spectral type, absolute magnitude (the latter an unworked field) and perhaps upon the region of the sky considered; the devising of a rapid method for the detection of moving clusters, and the identification of their members; and so on. The discussion of most of these problems should be based simultaneously on proper motions and radial velocities. Results derived from either one alone may fall into errors which the combination of both would detect.

One practical matter deserves specific mention. When it appears desirable to exclude certain stars from a statistical discussion (for example, those of very large proper motion), the limits of exclusion should be clearly and precisely stated. Neglect to do so may cause great trouble to other workers who wish to make a comparison with their own results, and has sometimes led to very serious errors of interpretation.

9. Another set of data of fundamental importance depend upon relations involving the *masses* of the stars. Here there appears the grave difficulty that nothing at all can at present be found out concerning the mass of a star unless it is double. There are plenty of double stars, to be sure; but what certainty have we that they are similar in mass to stars which are not double? Only an indirect answer is possible, by means of the statistical comparison of single and double stars with respect to as many characteristics as may be—absolute magnitude,

spectrum, color, radial velocity, proper motion, distribution in space, etc. (bearing in mind that the limits of telescopic resolution restrict our knowledge of the remoter pairs). But Eddington's recent theoretical researches[82] lead to the hope that it may some day be possible to estimate the mass of any star when its absolute magnitude and spectral type are accurately known (using the data for double stars as a guide).

(*a*) As regards the determination of the masses of individual stars, it should be borne in mind that, for statistical purposes, a pair in which the relative motion of the components is known, though the motion in angle may be only a few degrees, is very nearly as valuable as one which has completed a revolution—while a pair for which the relative motion is unknown is of no use at all. The slowly moving pairs which are often, but inaccurately, described as 'fixed,' possess an importance exactly analogous to the stars of small proper motion, and give us invaluable information about those stars which are bright in proportion to their mass—the giant stars, in fact. Now that the discovery of double stars is apparently in sight of completion, it is to be hoped that more attention may be given to the problem of determining the relative motion in as many systems as possible.

(*b*) The existing data suffice to show that the masses of the stars differ from one another less than any other of their characteristics—the whole range among well determined masses being from 20 times the Sun's mass to one-sixth of the Sun's, which may be compared with a range in luminosity of at least ten million fold. For this very reason, very careful observations are required to enable us to say with certainty that one star is more or less massive than another. It appears certain that the stars of spectrum B are unusually massive,[56] and there is sufficient evidence to show that, in general, stars of great luminosity are more massive than those of small absolute brightness, and that, among the dwarf stars, those of 'later' spectral type are of smaller average mass.[57] But there are very few cases in which we can be sure that a given star is more or less massive than the average for its type.

It is very desirable to determine how great is the range of difference among the masses of stars of similar spectral class or absolute magnitude. Extremely precise determinations of parallax will be needed if this problem is to be solved, but the effort will be well worth while. Sufficiently reliable values of the mean masses of stars of different groups have already been determined, to make it possible to estimate the parallaxes of all but the nearer binaries and 'physical pairs' more accurately than they can at present be observed.[57] This should be of aid in the interpretation of other statistical studies of double stars,

such as the proportion of double stars among all the stars of a given magnitude, the relative numbers of close and wide pairs, etc.

The determination of the relative masses of the components of binary systems will soon also be possible in many cases which have previously been somewhat neglected.

When a sufficient number of accurate determinations of mass have been made, a detailed study of the spectra of stars differing in mass should be made, in the hope of finding peculiarities depending directly on the mass, which might make it possible to estimate the masses of isolated stars.

(*c*) A great number of *spectroscopic binaries* await investigation, and more are continually being discovered. In the determination of orbits, preference should be given to those which show the spectra of both components, as it is only in this case that definite information can be obtained about the masses. Eclipsing and Cepheid variables are also worthy of special attention, and also stars of large proper motion, or others which appear to be dwarf stars.

It is very desirable that some method should be found for observing the spectrum of the secondary component when it is too faint to be directly seen. Perhaps Koch's spectromicrometer might furnish a solution. Favorable cases for trial, in which the brightness of the invisible secondary spectrum is known, may be found among eclipsing variables.

10. The *densities* of stars can so far be determined only when they are eclipsing variables. In this case, when both spectra can be photographed, the *diameters* of the components can also be found. Several systems of this sort, which have not yet been investigated spectrographically, are within the reach of existing instruments.

If, however, the relations between spectral type, color index, and surface brightness can be so well determined that it is possible to estimate the last of the three when the other two are known, it will then be possible to determine the densities of all visual binary stars, the linear diameters of all stars of known parallax, and the angular diameters of all the stars in the sky. The known eclipsing variables should afford sufficient material for a first investigation of the problem, if only sufficiently accurate information can be obtained regarding the color-equation of the visual and photographic methods of observation which have been employed at various observatories.

11. All that can be said at present regarding the *internal constitution* of the stars depends on Eddington's theoretical work,[82] which indicates that, in the stars of low density, the mass should be greatly condensed toward the center—the central density being 54 times the mean den-

sity. But the problem is capable of investigation by observation. There are many close eclipsing pairs in which the components are ellipsoidal in form, as is proved by variability of the Beta Lyrae type. In such systems the lines of apsides of the orbits should advance, at a rate depending on the masses, dimensions, and internal constitution of the components. If the last is like that of Jupiter or Saturn, the advance of periastron should be rapid. What little evidence there is indicates a slower motion, and hence a very strong central condensation; but more intensive studies are necessary before definite conclusions can be drawn. There are several systems for which the necessary data concerning the dimensions and forms of the orbits and the stars are accessible to suitably planned observations,—notably α Virginis and *U* Herculis. A careful study of such stars, by means of simultaneous photometric and spectroscopic observations, would be remunerative.

The singular and so far inexplicable changes which occur in the periods of most eclipsing variables, and so far have defied prediction, also deserve extended study; and Eddington has recently called attention to the fact that secular changes in the periods of Cepheid variables are likely to give a clue to the rate of stellar evolution.[58] The first scanty evidence points to a very extended time scale.

12. In the investigation of *star-clusters*, measures of position, for the purpose of detecting future proper motions, are obviously a duty to posterity. There is little chance that anything more than the motion of the clusters as a whole will be perceptible in our generation, and only measures of the utmost attainable accuracy and freedom from systematic error are likely to be of use to the astronomers of the future. Of far more promise are studies of the distribution of the stars within the clusters, their magnitudes, and, above all, their color indices. Such investigations, in Shapley's hands,[59] have given us for the first time a true conception of the distances and magnitudes of the globular clusters. Students of the subject are eagerly awaiting the detailed publication of the evidence on which he bases his conclusion that the apparent avoidance by these clusters of the region within 1500 parsecs of the galactic plane is due to a real absence of clusters from this region, and not to obscuration by absorbing matter.

The variable stars in clusters also deserve further attention. Those so far discovered appear to belong to the Cepheid type, which is natural, as these seem to be actually the brightest of all variables. Long period and eclipsing variables may yet be discovered among the fainter stars.

Good work can still be done also upon the irregular clusters,—as is shown by Trümpler's[60] study of the outlying members of the Pleiades.

One of the most attractive of unexplored fields is the investigation of the *Magellanic Clouds*. The small amount of work which has been done, mainly on the Smaller Cloud, has led to the discovery of a remarkable relation between the periods and absolute magnitudes of the variables in the Cloud,[61] to the estimate that its distance is 20,000 parsecs,[62] and to the discovery that the nebulae within it, and probably the Cloud as a whole, have a very high radial velocity.[63] The great instruments which are now being erected in the southern hemisphere may well be actively directed toward this region.

13. (*a*) Foremost among the many problems presented by the *gaseous nebulae* is the cause of their luminosity. In spite of our ignorance of the origin of the characteristic nebular lines, the appearance of such lines as λ 4686 in the spectra of nebulae, and of the Wolf-Rayet spectrum in their nuclei, suggests that in them "we are presented" (in Fowler's words)[64] "with phenomena which result either from the effects of powerful electrical actions or of very elevated temperatures." Though such conditions may easily enough exist in the nuclei, it is very hard to see how high temperatures can prevail throughout the whole volume of a nebula.* There are several possible ways out, however.

The electrical action may be a bombardment of the outer region by corpuscles emitted from the nucleus. Or perhaps the luminosity of the gases is fluorescent, like that of the sodium or bromine vapors studied by Wood.[66] Or, as Fabry has recently suggested,[67] we may have to do with a body which absorbs and emits radiation only in narrow regions of short wave-length, and may therefore attain a very high temperature in thermal equilibrium with the radiations from a distant, but still hotter, source. To determine the true explanation among these and many other possibilities may tax the resources of both experimental and theoretical spectroscopy.

The association of gaseous nebulae with stars of 'early' spectral type might be anticipated on any of these theories. For such stars are very hot bodies, and would be the most powerful sources both of corpuscular and ultra-violet radiation. Hence the association of these stars with nebulae does not prove that the stars originate from the nebulae. It is entirely conceivable that, on the contrary, the nebulae, as visible objects, owe their existence to the radiation of the stars, and are their offspring, and not their parents. Some gaseous nebulae, however, are not near bright stars, and the nuclei of planetary nebulae appear to be

* Fabry's calculated temperature of 15,000° for the Orion Nebula,[65] as he points out, is liable to be diminished by an unknown amount on account of the widening of the lines of the spectrum by turbulent motion of the nebular matter in the line of sight.

comparable with some of the faintest stars in luminosity. Clearly, nothing final can be said on this subject until we know what it is that shines in the gaseous nebulae, and why. It may be remarked, however, that the wide-spread assumption that the origin of the stars is to be sought in the visible nebulae appears to have had very little solid basis. All classes of nebulae except the extended gaseous nebulae have already been excluded from consideration as observational knowledge increased.

(*b*) A few nebulae, like those in the Pleiades,[68] appear to shine by light reflected from neighboring stars, and Slipher's spectroscopic work is steadily adding to the list of his discoveries in this field. Hertzsprung[69] has shown photometrically that the brightness of the nebulosity in the Pleiades is entirely consistent with the reflection hypothesis. Similar studies of other nebulae, and especially of the remarkable variable nebulae recently observed by Slipher,[70] would be of value.

Barnard's long continued researches[71] have made it highly probable that there exist many *dark nebulae*, revealed only by the effects of their opacity in concealing whatever lies beyond them. It is highly significant that the most remarkable of these dark regions is obviously directly connected with one of the nebulae which shines by reflected light,—that surrounding Rho Ophiuchi[72]—and that the whole mass is comparatively near us in space, at a distance of 100 to 150 parsecs. If such masses of practically opaque material are scattered through the galactic and extra-galactic regions at distances comparable with this, the resulting absorption of light must play a very important rôle in limiting the apparent extent of the universe. If this absorption is of the type which is produced by dust, or even by particles of the size of the drops of water in ordinary clouds, it will affect all wave-lengths to substantially the same extent, and be much more difficult to detect than the gaseous scattering, increasing for the shorter wave-lengths, which several investigators have sought for, but whose existence Shapley has apparently disproved.[73] It seems appropriate to remark in this connection that absorption independent of the wave length seems *a priori* much more likely to occur than the other, since the same quantity of matter in the form of a fog is incomparably more effective than in gaseous form, (compare the opacity of a few meters of cloud with that of all the rest of the atmosphere) and also since most forms of matter are likely to be in the solid or liquid state at the temperatures prevailing in interstellar space.

(*c*) The forms of nebulae—especially of planetary and ring nebulae—deserve careful study. As Campbell suggests,[73] it is difficult to account for them without assuming the existence of some repulsive force which

counteracts the attraction of the nucleus. He suggests light-pressure—which would fit in well with views of the origin of the luminosity such as are suggested above. In such a case we should anticipate that most of the light of the nebula would come from the nucleus, and this appears to be usually, though not always, the case.

(*d*) Measures of the radial velocities of nebulae have already shown that the planetary nebulae, as a class, are moving in space much more rapidly than the stars;[74] that there exist internal motions within them, usually of a rotational character, but sometimes more complicated;[73] and that, in order to keep the moving material from flying away into space, the total masses of the nebulae must be very considerable, and probably a good deal larger than those of the stars.[73] Much remains to be done in the investigation of these motions, and in their interpretation. The proper motions of planetary nebulae, and perhaps in some cases the internal motions of the nebular material, can be determined by comparison of suitable photographs, and it is probable that in a decade or two we shall obtain in this way a fair idea of the distances and real dimensions of these bodies. Observations for parallax on some of the larger and presumably nearer planetary nebulae are also desirable.

The extended gaseous nebulae should be examined spectrographically to see whether turbulent motions exist in others, as they do in the great nebulae of Orion;[75] and it would be worth while to compare photographs of some of those which show sharp details, in the hope of detecting proper motion, either of the whole or of parts.

Investigations of the distribution within the gaseous nebulae of the substances which give the different spectral lines may be made by photography either with absorbing screens or with slitless spectroscopes, and promise information regarding the conditions prevailing in the nebulae, and the mutual relations of the lines of unknown origin.

14. (*a*) The *spiral nebulae* have been shown by recent investigations to be the most extraordinary objects in the heavens. Their enormous radial velocities—first detected by Slipher[76]—and the almost equally rapid internal motions within them,[77] put them in a class by themselves. Further measures of these motions are needed; and, when the radial velocities of a sufficient number of spirals, well distributed over the heavens, are known, it may be possible to determine definitely the direction and rate of the motion of the Sun (and presumably of the whole galactic system) with respect to the system of nebulae. The provisional determination by Young and Harper,[78] from very scanty data, indicates for the motion of our system the enormous velocity of 600 kilometers per second.

(*b*) As van Maanen[79] and others[80] have shown, the proper motions of some spiral nebulae—both of the mass as a whole and of the condensations in the arms relatively to the centre—are apparently large enough to be determined by the careful comparison of plates taken only a few years apart. This opens up another wide field of study, and will make it possible before long to determine the mean parallax of many such nebulae by comparison of the proper motions and radial velocities of their nuclei. There is also reason to hope that the distances of some individual nebulae, which are seen at a suitable angle, can be determined by comparing the radial and transverse components of motion along the arms. Enough is already known to convince us that the distances of these nebulae must be measured in thousands of parsecs, and their diameters in parsecs, and that direct measures for parallax are utterly hopeless.

(*c*) Photometric measures, both of the total light of the spirals and the relative brightness of their parts, would be of value, especially if accompanied by determinations of color. Seares[81] has recently shown that the outer convolutions are far bluer than the centre—which is the part that shows the spectrum of solar type. Spectroscopic observations of these outer regions, if possible, would be of great interest. Another matter calling for further study is the nature of the dark bands which cross many nebulae which appear to be spirals seen edgewise, and look as if they were due to the interposition of opaque material in the outer regions of the nebula.

(*d*) The distribution of spiral nebulae in the heavens—so utterly different from that of any other objects—may be explainable when their real distribution in space is even partially known. It is hardly time as yet to consider the greater question of their real nature, except to note, with van Maanen,[79] that, unless they are in process of very rapid dissipation into space, their masses must be exceedingly great.

15. Finally, it must not be forgotten how important a place *theoretical investigations* will occupy in the solution of the larger problems of sidereal astronomy. The increasing observational data are already furnishing just those guides which point the skilled mathematician in the right direction, and these indications have been very successfully followed, especially by certain members of that 'Cambridge school' which combines keen mathematical analysis with a thorough knowledge of modern physics. Results of remarkable generality have already been obtained.

In the field of stellar evolution, Eddington[82] has worked out in detail the importance of radiation pressure in determining the conditions of internal equilibrium of the stars, and the approximate equality in

brightness of the giant stars of all spectral types has found a simple explanation.

If the conclusion that the luminosity of a giant star is a function of its mass, but not of its temperature or age, is confirmed, and the nature of the function fixed by observation, the problem of determining the masses of stars which are not double will in many cases be solved.

Jeans,[83] discussing the problem of the figures of equilibrium of a rotating mass of compressible fluid, has already reached conclusions which not only bear upon the origin of double stars, but have suggested an entirely new and very stimulating conception of the nature of spiral nebulae, as huge rotating masses of gas, which, becoming unstable at the edge under the influence of their own rotation and the attraction of the neighboring stars, throw off matter from their periphery in streams of such enormous size that they may divide into 'nuclei' large enough to form ordinary stars upon condensation.

In the field of galactic astronomy, Schwarzschild[84] has developed powerful methods for handling the statistical material which must be our main guide, and Jeans[85] and Eddington[86] have shown that 'star streaming' demands no unknown forces for its explanation, but is probably interpretable dynamically, as a property of a system of stars in motion under their own gravitation—although the existence of 'streaming' appears to indicate that the galactic system is not in a 'steady state.' Eddington[87] has shown that the similarity of distribution of the stars in different globular clusters presents a problem by no means simple, though of much interest.

Almost the whole of this work has appeared within the last three years, and further notable advances may be anticipated. Indeed, almost as these words are written, comes the first installment of an important paper by Eddington[88] on the oscillations of a gaseous star, which may afford the long-sought solution of the problem of Cepheid variation.

Among other specific problems awaiting discussion may be mentioned the question whether the tidal interaction of two compressible and slowly condensing bodies can cause an originally small eccentricity to increase to the very large values which are found in many visual binaries, and some spectroscopic binaries as well; and, if this proves to be impossible, how the systems in question can have originated;[89] the origin and laws of the complicated changes which occur in the periods of many eclipsing binaries; and the equilibrium and motions of the constituent parts of planetary and spiral nebulae.

Mention should also be made of the work of Nicholson[90] on the interpretation of unknown lines in the spectra of nebulae and of the

solar corona as arising from hypothetical atoms of very simple structure —which has successfully met the test of prediction—and of the development of the theory of general relativity, which has already been used by deSitter[84] to set a superior limit to the whole quantity of matter in the universe, and may have important applications in future.

16. Of more fundamental nature, and obvious importance, is the unsolved problem of the source of the energy which the stars are continually radiating at so rapid a rate. It is becoming increasingly plain that the gravitational energy liberated by contraction from infinity would not nearly suffice to maintain the Sun's radiation during geological time[90] (according to even the more conservative estimates of the latter); yet the mere continuous existence of life on the Earth is evidence that the Sun has not merely kept on shining throughout this interval, but has not changed in brightness by more than one magnitude, at the outside. In the case of some giant stars, contraction from infinity would hardly suffice to furnish the energy which they have radiated during historic time.[91] There appear to be two ways out of the difficulty; either the stars do not radiate heat in all directions to space at the same rate as they do towards the Earth, or else they have some unknown and exceedingly great supplies of internal energy. The first alternative, however, seems to be excluded by the fact that the amount of heat which the Earth receives from the Sun, and loses again by radiation into space, is not greatly, and probably not at all, inferior to that which a black body of the same size and temperature as the Earth's effective radiating surface would radiate to an enclosure at the absolute zero.[92] There seems therefore no escape from the conclusion that the heat radiated by a star can not be provided by contraction. What the source of the energy may be, how it is converted into heat in the body of the star, and where it goes after passing from the star's surface into the ether, are at present the greatest of all the unsolved problems of astronomy.

[1] Newall, Baxandall and Butler, *Monthly Not. Roy. Astron. Soc., London* **76**, 1916, (640).
[2] Fowler, A., *Proc. Royal Soc., London*, A, **94**, 1918, (470).
[3] Fowler, A., *Ibid.*, A, **94**, 1918, (472).
[4] Fowler and Brooksbank, *Monthly Not. R. A. S., London*, **77**, 1917, (511–517).
[5] *Astrophy. J., Chicago*, **40**, 1914, (466–472).
[6] Curtiss, R. H., *Popular Astronomy, Northfield, Minn.*, **25**, 1917, (279–285).
[7] Cannon, Miss A. J., *Ibid.*, **24**, 1916, (656).
[8] Adams, W. S., these PROCEEDINGS, **2**, 1916, (143).
[9] Hertzsprung, E., *Z. Wiss. Photog., Leipzig*, **3**, 1905, (429–435).
[10] Adams, W. S., these PROCEEDINGS, **2**, 1916, (147–156).
[11] See Ref. 6; also Rufus, W. C., *Pub. Astron. Obs. Univ. Michigan, Ann Arbor*, **2**, 1916, (143).

[12] King, E. S., *Ann. Harvard Coll. Obs.*, *Cambridge*, **76**, 1915, (119).
[13] Merrill, P. W., *Popular Astron.*, *Northfield*, **25**, 1917, (661).
[14] Adams, W. S., *Astroph. J.*, *Chicago*, **33**, 1911, (64–71).
[15] Coblentz, W. W., *Lick. Obs. Bulletin*, *Berkeley, Cal.*, **8**, 1915, (104–120).
[16] Wilsing and Scheiner, *Publ. Astrophys. Obs.*, *Potsdam*, **19**, 1909, (5–221).
[17] Rosenberg, H., *Astron. Nach. Kiel*, **193**, 1912, (357–370).
[18] See *Harvard Annals*, **64**, 126–127.
[19] King, E. S., *Ibid.*, **76**, 1915, (189).
[20] Hertzsprung, E., *Astrophys. Jour.*, **42**, 1915, (92–110).
[21] Seares, F. H., these PROCEEDINGS, **2**, 1916, (521).
[22] Shapley, H., these PROCEEDINGS, **2**, 1916–17, (12–15) and **3**, (267–270).
[23] King, L. V., *Trans. Roy. Soc. Canada*, *Ottawa*, **9**, 1915, (99–103).
[24] Color index of ζ Persei + 0.16; color index of ξ Persei + 0.03; King, E. S., *Harvard Annals*, **76**, 1915, (118). Color index of o Persei; similar to that of a star of spectrum F., Wilsing and Scheiner, Potsdam Publ. **19**, 1909, (64).
[25] Barnard, E. E., *Astrophys. Jour.*, **41**, 1915, (253–258).
[26] Coblentz, W. W., *Lick Obs. Bull.*, **8**, 1915, (121).
[27] Hertzsprung, E., *Astrophys. Jour.*, **42**, 1915, (352–356).
[28] *Harvard Circular*, *No. 188*, 1915.
[29] Cannon, Miss A. J., *Harvard Annals*, **91**, 1918, (274), (star No. 1546).
[30] Stebbins, J., *Pop. Astron.*, **25**, 1917, (657), and earlier papers.
[31] Guthnick, P., *Vierteljahrsschrift d. Astron. Gesellsch.*, **53**, 1918, (169).
[32] Shapley, H., *Astrophys. Jour.*, **43**, 1916, (180).
[33] Cannon, Miss A. J., *Pop. Astron.*, **25**, 1917, (314).
[34] Shapley, H., *Astrophys. Jour.*, **44**, 1916, (273–291).
[35] Shapley, H., *Ibid.*, **40**, 1914, (448–465).
[36] See numerous notes by Mrs. W. P. Fleming, *Harvard Annals*. **56**, (209–212).
[37] Adams, W. S. and Pease, F. G., these PROCEEDINGS, **1**, 1915, (391).
[38] Cannon, Miss A. J., *Harvard Annals*, **76**, 57.
[39] Hertzsprung, E., *Astrophys. Jour.*, **42**, 1915, (118).
[40] Kapteyn, J. C., *Ibid.*, **40**, 1914, (118–126).
[41] Russell, H. N., and Shapley, H., *Ibid.*, **40**, 1914, (422–423).
[42] Shapley, H., *Ibid.*, **48**, 1918, (282–287).
[43] Hertzsprung, E., *Zeitschr. f. Wiss. Phot.*, **3**, 1905, (442).
[44] Russell, H. N., *Pop. Astron.*, **22**, 1914, (275–294 and 331–357).
[45] Adams, W. S., these PROCEEDINGS, **2**, 1916, (157–163).
[46] Kapteyn, J. C., *Astrophys. Jour.*, **47**, 1918, (255–275).
[47] Russell, H. N., *Observatory*, *London*, **37**, 1914, (167–169).
[48] Strömberg, G., *Astrophys. Jour.*, **47**, 1918, (14).
[49] For example, the mean absolute magnitude given by Adams, (*Mt. Wilson Contribution*, No. 142) for the four Cepheid variables and eight other stars of Miss Maury's classes *c* and *ac* which, appear in his list, is + 0.3; and there is abundant evidence from the parallactic motions that the mean absolute magnitude of the stars of this peculiar class is at least as bright as − 2, and probably brighter.
[50] Kapteyn, J. C., *Astrophys. Jour.*, **47**, 1918, (263).
[51] Adams, W. S., *Publ. Astron. Soc. of the Pacific*, **27**, 1915, (236).
[52] Adams, W. S., *Ibid.*, **26**, 1914, (198).
[53] Comstock, G. C., *Astron. Journal*, *Albany*, **25**, 1907, (119).
[54] Barnard, E. E., *Ibid.*, **29**, 1916, (181).
[55] See summary in *Monthly Not. Roy. Ast. Soc.*, **78**, 1918, (304).
[56] Ludendorff, H., *Astron. Nach.*, **189**, 1911, (145–155).
[57] Russell, H. N., *Pop. Astron.*, **25**, 1917, (666).
[58] Eddington, A. S., *Monthly Not. Roy. Ast. Soc.*, **79**, 1918, (19).

[59] Shapley, H., *Astrophys. Jour.*, **48**, 1917–18, (89–124, 154–181).
[60] Trümpler, R., *Pop. Astron.*, **26**, 1918, (9).
[61] Leavitt, Miss H., *Harvard Circular*, **173**, 1912.
[62] Shapley, H., *Astrophys. Jour.*, **48**, 1918, (155).
[63] Wilson, R. E., *Pub. Ast. Soc. Pacific*, **27**, 1915, (86).
[64] Fowler, A., *Monthly Not. Roy. Ast. Soc.*, **77**, 1917, (516).
[65] Fabry, *Astrophys. Jour.*, **40**, 1914, (256).
[66] Wood, R. W., *Physical Optics*, 2d ed. (New York, 1911), p. 583.
[67] Fabry, *Astrophys. Jour.*, **45**, 1917, (269–277).
[68] Slipher, V. M., *Lowell Observatory Bulletin*, **2**, 1912, (24).
[69] Hertzsprung, E., *Ast. Nach.*, **195**, 1913, (449).
[70] Slipher, V. M., *Lowell Obs. Bull.*, **3**, 1918, (63).
[71] Bannard, E. E., *Astrophys. Jour.*, **49**, 1919, (1).
[72] Slipher, V. M., *Lowell Obs. Bull.*, **2**, (155).
[73] Campbell, W. W., *Pub. Ast. Soc. Pacific.*, **29**, 1916, (284).
[74] Campbell, W. W. and Moore, J. H., *Ibid.*, **27**, 1915, (240).
[75] Fabry, *Astrophys. Jour.*, **40**, 1914, (241).
[76] Slipher, V. M., *Pop. Astron.*, **23**, 1915, (23).
[77] Slipher, V. M., *Lowell Obs. Bull.*, **2**, 1914, (66).
[78] Young and Harper, *Jour. Roy. Ast. Soc. Canada*, **10**, (134.)
[79] van Maanen, A., *Astrophys. Jour.*, **44**, 1916, (210–228).
[80] Kostinsky, S., *Monthly Not. Roy. Ast. Soc.*, **77**, 1917, (233).
[81] Seares, F. H., these PROCEEDINGS, **2**, 1916, (553).
[82] Eddington, A. S., *Monthly Not. Roy. Ast. Soc.*, **77**, 1916–17, (16 and 596); also *Astrophys. Jour.*, **48**, 1918, (205).
[83] Jeans, J. H., *Observatory*, **40**, 1917, (60).
[84] Schwarzschild, K., *Astron. Nach.*, **190**, 1912, (361), and **198**, 1914, (217).
[85] Jeans, J. H., *Monthly Not. Roy. Ast. Soc.*, **76**, 1915–16, (70 and 552).
[86] Eddington, A. S., *Ibid.*, **74**, 1913, (5), and **75**, 1916, (366), and **76**, 1916, (37).
[87] Eddington, A. S., *Ibid.*, **76**, 1916, (572–585).
[88] Eddington, A. S., *Ibid.*, **79**, 1918, (2).
[89] Nolke, F., Abh. Nat. Ver. Bremen, **20**, Teil 2, 1911, (193–220). Jeans, J. H., *Observatory*, **42**, 1919, (40).
[90] Shapley, H., *Pub. Ast. Soc. Pacific.*, October, 1918, (283–298).
[91] Eddington, A. S., *Monthly Not. Roy. Ast. Soc.*, **79**, 1918, (19).
[92] Abbot, G. G., these PROCEEDINGS, **4**, 1918, (104–106).
[93] Nicholson, J. W., *Monthly Not. Roy. Ast. Soc.*, **76**, 1916, (415); **78**, 1918, (349), and earlier papers.
[94] deSitter, W., *Ibid.*, **78**, 1917, (25).
[95] As this paper goes to press, van Maanen, (*Pub. Ast. Soc. Pacific*, **31**, 1919, (42)) announces the discovery of a star of type F, and absolute magnitude 14.3 on Kapteyn's scale. If the surface brightness of this object has the value which is ordinarily associated with its color and spectrum, its diameter must be comparable with that of the Earth. These faint stars are evidently going to present a problem of great interest and difficulty.

ON THE SPECTRAL LINES OF A PULSATING STAR

By Harlow Shapley and Seth B. Nicholson

Mount Wilson Observatory, Carnegie Institution of Washington

Communicated by G. E. Hale, July 21, 1919

The hypothesis that the periodic variations in light and spectrum of a Cepheid variable are due to radial expansion and contraction of a single stellar body demands a behavior in the periodic oscillation of the spectral lines which is decidedly different from the behavior of the absorption lines of an ordinary spectroscopic binary star. In the latter case the line-shifts show, in accordance with the Doppler effect, the orbital motion of the star as a whole; in the former case the displacements of the spectral lines depend on the radial velocity of the part of the stellar disk from which the light emanates. The radial velocity due to a spherical pulsation diminishes from a maximum value at the center of the stellar disk to zero at the limb; the shifts, therefore, are not true bodily displacements of the normal spectral line, as in the case of orbital motion, but represent a broadening toward the violet while the star expands and toward the red while it contracts. Obviously a lack of symmetry as well as a widening is produced; but if the total displacement, due to radial movement of the absorbing layers, is of the same magnitude as the inherent width of the lines, it is clear that the asymmetrical broadening may not be readily noticed or measured. The object of this note is to examine in some detail the character of the spectral lines of a pulsating star.

For a star of unit radius undergoing alternate expansion and contraction symmetrically about the center, the radial velocity, in terms of its maximum value, for any point on the visible hemisphere is $v = \sqrt{1 - r^2}$, where r is the distance from the center of the apparent disk. Hence

$$r = \sqrt{1 - v^2} \tag{1}$$

The usual law of darkening, which has been found satisfactory in the case of the sun and eclipsing stars[1] and has subsequently been derived by Jeans[2] in his theory of stellar photospheres, may be written

$$\frac{J}{J_0} = 1 - x + x\sqrt{1 - r^2}$$

where J/J_0 is the surface intensity at the distance r from the center in terms of the central intensity, and x is the so-called darkening

coefficient. Then the total light of a star is given by

$$L = J_0 \int_0^{2\pi} \int_0^1 (1 - x + x\sqrt{1 - r^2})\, r dr d\theta$$

Introducing (1) and integrating once

$$L = 2\pi J_0 \left[\int_0^1 v\,(1 - x)\, dv + \int_0^1 v^2 x dv \right] \tag{2}$$

Suppose that from any given element of surface the width of the absorption lines is very small compared with the displacement due to radial motion of the element; and let the amount by which the continuous spectrum is decreased by a given absorption line be $L' = L$ *times* a constant. The equation of the intensity curve of a line in the spectrum of the whole surface would then be $\frac{I}{I_0} = \frac{dL'}{d\lambda}$ which may be written $\frac{dL'}{dv}$ because of the essentially linear relation (throughout very short intervals of the spectrum) between wave-length, λ, and velocity; and hence, from (2),

$$\frac{I}{I_0} = 2\pi \left[v\,(1 - x) + v^2 x \right] \tag{3}$$

where I_0 is the intensity for maximum absorption ($v = 1$) divided by 2π and is independent of the degree of darkening.

For a uniform disk $x = 0$ and

$$\frac{I}{I_0} = 2\pi v \tag{4}$$

while for one darkened to zero at the limb, $x = 1$, and

$$\frac{I}{I_0} = 2\pi v^2 \tag{5}$$

These intensity curves are plotted in figure 1. For a star of the spectral character of the sun, x is $\frac{3}{4}$ in the neighborhood of $\lambda = 4400$ A. Therefore

$$\frac{I}{I_0} = \frac{\pi}{2}(v + 3v^2)$$

and the intensity curve lies between those for uniform and completely darkened disks, but much nearer the latter, as shown by the broken curve in figure 1.

It is obvious from the above discussion that darkening at the limb will aid in concealing whatever asymmetry there may be in the spectral

lines of a pulsating star. From the eclipsing stars that most resemble the typical Cepheid variable stars in density, spectral type, and absolute luminosity, there is evidence in certain cases that the light diminishes more rapidly toward the limb than required by the above law. On the other hand, however, the relative intensity in the violet region of the continuous spectrum of Cepheids and other giant F-type stars

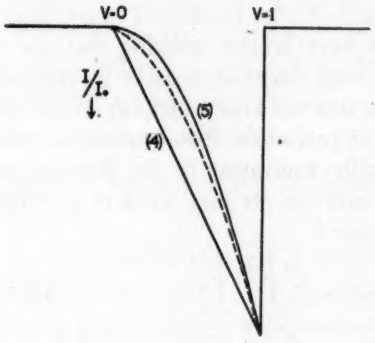


FIG. 1

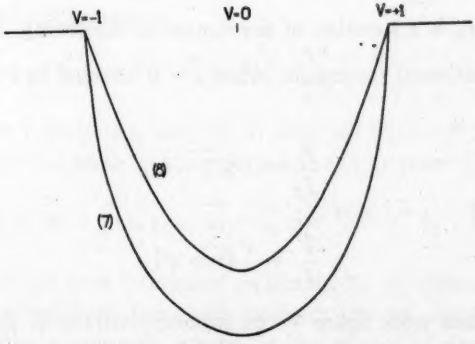


FIG. 2

may be urged against the assumption of excessive darkening. In any case, in view of the existence of large numbers of strong absorption lines throughout the spectra, it may be accepted that Cepheid variables are considerably darkened at the limb. For them the coefficient x may be reasonably assumed to lie between one-half and unity.

The preliminary assumption that spectral lines are inherently infinitesimal in width is of course untrue. Even if the radiation concerned

were strictly monochromatic the spectral lines would have a finite width since the resolving power of a spectrograph is not infinite. As is well known, however, the light giving rise to an absorption line is by no means monochromatic. Its distribution may be represented satisfactorily by

$$\frac{I'}{I_0'} = e^{-h^2\lambda^2} = e^{-h^2v^2/c^2} = e^{-h^2(v-v_n)^2} \tag{6}$$

where v_n is the value of v for intensity I', corresponding to maximum absorption. The form of the resulting line, as reproduced by the spectrograph, has been discussed in detail by Wadsworth.[3]

Rotation of the star will also contribute to the widening of spectral lines. Since v, the projection of the rotational velocity in the line of sight, is numerically equivalent to the distance on the stellar disk from the axis of rotation, we may write $r^2 = v^2 + y^2$. Therefore the total light of the star is

$$L = \iint J\, dv\, dy = J_0 \int_{-\sqrt{1-y^2}}^{+\sqrt{1-y^2}} \int_{-1}^{+1} [\,(1-x) + x\sqrt{1-v^2-y^2}\,]\, dv\, dy$$

and

$$\frac{I}{I_R} = 2\,(1-x)\sqrt{1-v^2} + \frac{\pi x}{2}\,(1-v^2)$$

In this case I_R is a function of the degree of darkening, being the intensity for maximum absorption (when $v = 0$) divided by $2\,(1-x) + \frac{\pi x}{2}$.

Then for $x = 0$

$$\frac{I}{I_R} = 2\sqrt{1-v^2} \tag{7}$$

and for $x = 1$

$$\frac{I}{I_R} = \frac{\pi}{2}\,(1-v^2) \tag{8}$$

For comparison with figure 1, the intensity curves of the absorption lines for a rotating star (assuming monochromatic radiation and infinite resolving power) are shown in figure 2.

It can be shown without difficulty that if for an average Cepheid the period of rotation is less than two months the widening of the lines due to rotation will be decidedly greater than the widening due to pulsation.

Obviously, then, rotation of the star, resolving power, and the inherently finite width will all affect the appearance of the absorption lines, independently of changes due to pulsation. If the resolution is

not too small, however, and the widening due to rotation is not too large compared with the normal width of the line, these three factors will not appreciably affect the *form* of the line given by (6). The narrowest lines observed in stellar spectra are in width rarely less than 0.2A, which is of the same order as the semi-amplitude of the shift for a typical Cepheid variable.

The true form of a line in the spectrum of a pulsating star is therefore not as given in figure 1, but may be approximated by integrating (6) over the whole surface of the star. Any given incremental annulus on the stellar disk has a velocity v_n and contributes an incremental spectral line whose intensity curve is given by (6):

$$I' = I'_0 \, e^{-K^2(v-v_n)^2}$$

The intensity of this line for maximum absorption, I'_0, occurs for $v = v_n$; and hence from (3),

$$I'_0 = I_n = 2\pi \, I_0 \, [v_n \, (1 - x) + v_n^2 \, x] \tag{9}$$

Substituting (9) in (6)

$$I' = 2\pi \, I_0 \, [v_n \, (1 - x) + v_n^2 \, x] \, e^{-K^2(v-v_n)^2}$$

and summing up these incremental lines for all chosen values of v_n from 0 to 1, we obtain, as closely as we care to compute, the intensity curve from the whole surface:

$$I'' = F \, (v, x) = \sum_{v_n=0}^{1} I'$$

Writing $c\lambda = v$ from (6), and $I''_0 = 2\pi I_0$, we have, in the limit, for the intensity of the built-up absorption line at any point λ,

$$\frac{I''}{I''_0} = f \, (\lambda, x) = \int_0 [v_n \, (1 - x) + v_n^2 \, x] \, e^{-K^2(c\lambda - v_n)^2} \, dv_n \tag{10}$$

Equation (10) has been integrated mechanically for different values of x and different ratios of line width to displacements; figures 3a and 3b show the resulting intensity curves for line widths of about 0.4A and 0.2A, respectively, adopting in both cases a radial velocity that would yield a measured displacement of about 0.3A. From these curves we obtain the results of the following table:

	WIDTH OF UNDISPLACED LINE	WIDTH OF DISPLACED LINE		MEASURED DISPLACEMENT		ACTUAL DISPLACEMENT AT CENTER OF DISK
		$x=\frac{1}{2}$	$x=1$	$x=\frac{1}{2}$	$x=1$	
From figure 3a.....	0.34A	0.40A	0.38A	0.30A	0.32A	0.40A
From figure 3b.....	0.17A	0.23A	0.22A	0.32A	0.33A	0.40A

The last three columns of the table show that, if the pulsation hypothesis is correct, the measured range in velocity is about 75% of the actual variation at the center of the disk.

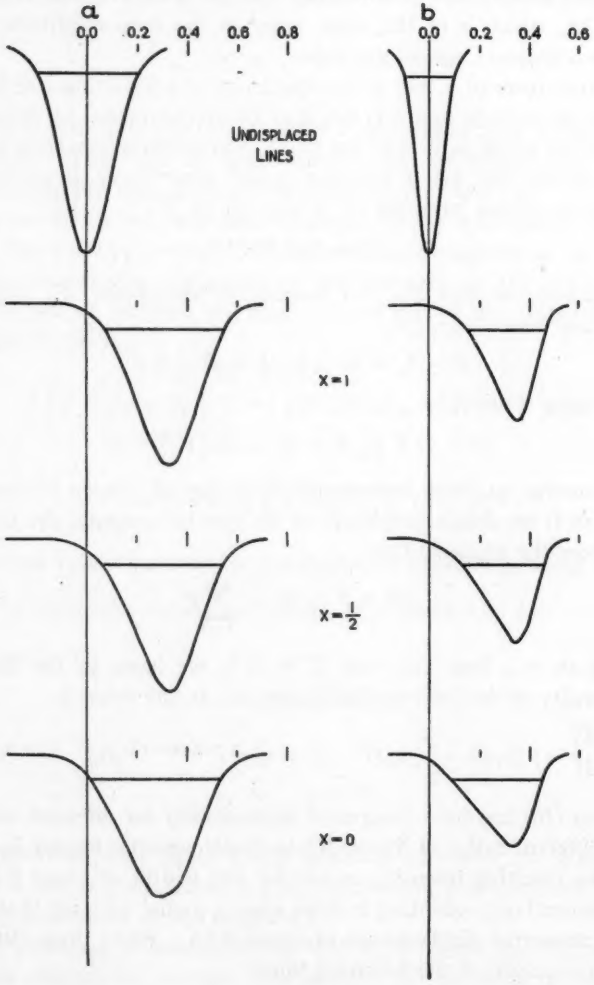


FIG. 3

There is considerable uncertainty in measures of the widths of absorption lines by ordinary methods, but it has been assumed that the measured widths lie between intensities of $\frac{1}{4} I'_0$, where I'_0 is the in-

tensity at maximum absorption of the undisplaced spectral line. It has also been assumed that the setting for the position of a line is such that the area under the intensity curve is divided equally and that the effect of absorption which is less than $\frac{1}{8} I_0'$ will not be appreciated; the results, however, are but slightly affected by the value assumed, provided it is within reasonable limits.

The lines of the spectrum of δ Cephei are much wider at minimum than at maximum light (and velocity).[4] Those shown in figures 3a and 3b are of the same width as observed in the case of δ Cephei at minimum and maximum, respectively, when a stellar spectograph of high dispersion and resolving power is used. The change observed in line width, according to results by Adams and by Young,[5] appears to have twice the period and about three times the amplitude of the variation which would be produced in a pulsating star by the distribution of velocity over the stellar disk; this latter variation, therefore, although it might be measurable if isolated, would probably be completely masked by the larger variation due to other causes.

Since practically all of the asymmetry is above the limit $\frac{1}{8} I_0'$ any deviation from a symmetrical form of the absorption lines would at all phases of the pulsation be inconspicuous on a spectrogram, and the lines would appear to be shifted bodily. The asymmetry would be most pronounced at maximum when the lines are comparatively narrow; but even then it seems doubtful if it could be observed if we are right in assuming that the lines for a Cepheid at maximum are best represented by curves such as those shown in figure 3, with values of x between $\frac{1}{2}$ and 1.

We conclude from these results that it is doubtful if either the periodic broadening or the slight asymmetry of the lines, due to a distribution of velocity over the stellar disk in accordance with the pulsation hypothesis, could be observed by any method thus far used.

[1] Shapley, Harlow, *Mt. Wilson Contr.*, No. 99, *Astrophys. J., Chicago, Ill.*, 41, 1915 (291–306), pp. 292–295.

[2] Jeans, J. H., *Mon. Not. R. Astr. Soc., London*, 78, 1917 (28–36), p. 35.

[3] Wadsworth, F. L. O., *Phil. Mag., London*, Series V, 43, 1897 (317–343).

[4] Adams, W. S., *Observatory, London*, 42, 1919 (167–168).

[5] Young, R. K., *J. R. Astr. Soc. Canada, Toronto, Can.*, 13, 1919 (45–54).

ETHYLENE CHLORHYDRIN

By M. Gomberg[1]

Chemical Laboratory, University of Michigan

Communicated, July 30, 1919

Within a few days after the so-called "Mustard Gas" was introduced (July 12–13, 1917) as a means of offence, it was definitely identified as β-β-dichlorethylsulphide. There was good reason to believe that it had been manufactured from ethylene chlorhydrin, according to the method described some thirty years previously by V. Meyer.[2] The reactions involved in that method are these: (1) Ethylene chlorhydrin in solution reacts with sodium sulphide and gives, in good yield, dihydroxyethylsulphide, which is non-poisonous; (2) this product gives on treatment with concentrated hydrochloric acid the highly toxic β-β-dichlorethylsulphide:

$$2\ HOCH_2CH_2Cl + Na_2S = (HOCH_2CH_2)_2S + 2\ NaCl$$
$$(HOCH_2CH_2)_2S + 2\ HCl = (ClCH_2CH_2)_2S + 2\ H_2O$$

The problem however was,—how to get the chlorhydrin itself? From the practical standpoint, a process based upon the additive reaction between ethylene and hypochlorous acid seemed most promising, notwithstanding the facts that this acid could only resist in concentrations of 1 to 3%, and that the best yield of chlorhydrin by this method was known to be not more than 30% of the theory.

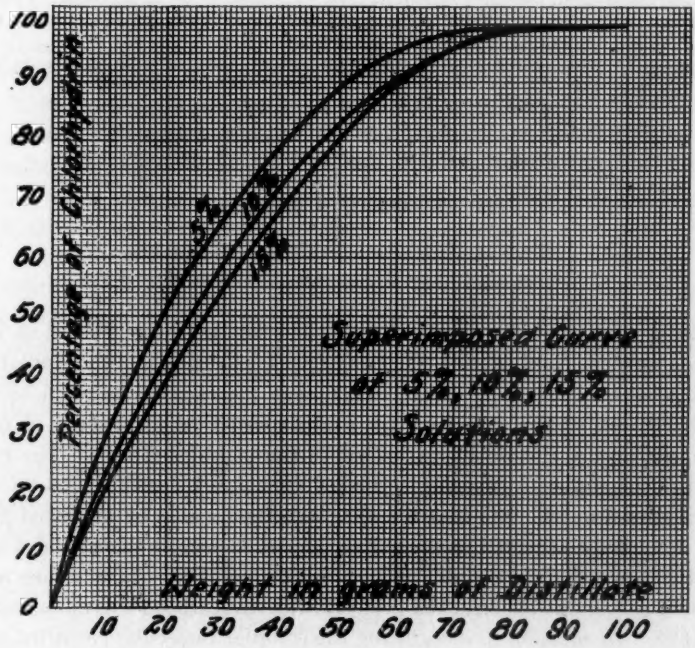
The reaction between chlorine and water was employed as the source of hypochlorous acid. As is well known, this reaction yields extremely little hypochlorous acid, the equilibrium favoring largely the left-hand side of the equation. Nonetheless, it was found that if ethylene and chlorine in equimolecular amounts are passed into cold water and the mixture is well stirred, chlorhydrin, and not ethylene chloride, is the principal product. This is explained on the assumption that reaction II proceeds with considerably greater velocity than reaction I.

$$\begin{array}{lccl} \text{I} & HOH + Cl & \rightleftharpoons & HOCl + HCl \quad \text{II} \\ & C_2H_4\downarrow & & \downarrow C_2H_4 \\ & C_2H_4Cl_2 & & ClC_2H_4OH \end{array}$$

While a concentration up to 15% of chlorhydrin can be attained in this way, in practice it has been found advisable to stop with a concentration of 7 to 8%. The progress of the reaction is ascertained by distilling a small sample of the product and determining its refractive index, that of water being 1.333 while that of chlorhydrin was found to be 1.442.

It was established that not only is it unnecessary to keep on neutralizing the hydrochloric acid produced with the progress of the reaction, but that in fact it is inadvisable to do so.

Separation of chlorhydrin.—Pure chlorhydrin boils at 128°C. It was found, however, that when mixed with water in proportion of 42.5 parts of the former and 57.5 parts of the latter, the two form a constant boiling mixture which distills at 95.8°. Consequently, aqueous solutions of chlorhydrin poorer than 42.5% tend to give on distillation initial frac-



tions approaching in composition the constant boiling mixture; solutions richer than 42.5% give as the final fractions pure chlorhydrin. With the addition of salt or calcium chloride to the liquid to be distilled, concentrations of chlorhydrin up to 80% can be readily obtained. The diagram shows what happens when 5, 10 and 15% solutions of chlorhydrin are subjected to distillation.

Chlorhydrin is miscible with water in all proportions. It has, however, been found that it can be salted out from its aqueous solutions, provided that the proper conditions as to initial concentration, etc., are

observed. Solutions containing 70% of chlorhydrin can readily be obtained in this manner.

It was also found possible to extract the chlorhydrin from its aqueous solutions by some immiscible solvent, benzene suggesting itself as the best from the practical standpoint. Thus, by a judicious combination of the three methods,—distillation, salting out and extraction,—chlorhydrin could readily be obtained in any desired concentration and purity.

[1] The investigation was done under the auspices of the Bureau of Mines, War Gas Investigations Department, December 1917–July, 1918. The paper in detail, approved for publication by Major-General William L. Sibert, Director of the Chemical Warfare Service, U. S. A., will appear in the *Journal of the American Chemical Society*.

[2] Meyer, V., *Berlin, Ber. D. chem. Ges.*, **19**, 1886, (3260), Clarke, H. T., *London, J. Chem. Soc.*, **101**, 1912, (1583).

STUDIES OF THE CONSTITUTION OF STEEL

By Edward D. Campbell

Chemical Laboratory, University of Michigan

Communicated by M. Gomberg, July 30, 1919

Researches on steel, considered as a solid solution, were carried on in this laboratory by the late J. W. Longley prior to 1876.[1] Other investigations of iron and steel were carried on in the interval between 1876 and 1891, at which latter time the present writer began a series of researches on the chemical constitution of the carbides of iron. The results of these investigations have gone to show that the carbides found in steel have a much more complex structure than would be indicated by the commonly accepted formula Fe_3C. The idea that the carbides of iron and many other metals can best be studied if the carbides are regarded as metallic substitution products of hydrocarbons was advanced[2] in 1896. In addition to recognizing the complex molecular constitution of the carbides, the assumption has been made that the atomic relations existing between the carbides or other solutes dissolved in iron are essentially the same as those which exist between the molecules of substances in aqueous solution and the water in which they are dissolved. Some further evidence in support of the hypothesis of the unity of mechanism of all solutions without regard as to whether the solvent is solid or liquid, metallic or a non-conductor of electricity, is given in two papers, one of which will be read at the Autumn meeting of the Iron and Steel Institute and the other at a forthcoming meeting of the Faraday Society.

In the first of these it is shown that from twelve samples of steels, including straight carbon steel, high silicon, high phosphorus, manga-

nese, five nickle steels, chrom-steel, chrom-tungsten and chrom-molybdenum steel, most of the carbon and a considerable proportion of the sulphur may be removed by heating bars of the metal in a slow stream of moist hydrogen, the temperature being maintained for from four to twelve days between 950°C. and 1000°C. Since the elements other than carbon and sulphur are not affected by hydrogen, this method of treatment affords a very satisfactory means of changing the carbide concentration without material change in composition, since the percent of sulphur is usually quite low in commercial steels.

The experimental data given in the second paper, "The Solution Theory of Steel and the Influence of Changes in Carbide Concentration on the Electrical Resistivity" demonstrate clearly that Benidicks' Law,[3] "Equiatomic concentrations in iron possess equal resistivities," is not tenable. It is the molecular, not the atomic concentration in metallic solutions, which determines the electrical resistivity, just as it is the molecular and not the atomic concentration which determines conductivity in aqueous solutions.

The fallacy contained in the conclusion drawn by Le Chatelier[4] that chromium, tungsten and molybdenum have but slight influence on the electrical resistance of steel, may be explained by the fact that when these elements are present in steel, they form with carbon complex carbides, so that the molecular concentration of the carbides is little if any greater than if chromium, tungsten and molybdenum were absent. If, however, the carbon is removed, the chromium, tungsten or molybdenum will itself combine with or dissolve in the iron, each thus producing an increase in electrical resistivity nearly equal to that which would be produced by an equal atomic concentration of carbon alone.

The force-field theory of solution developed by E. C. C. Baly[5] by a series of investigations of the action of light on aqueous solutions, may be applied to solid solutions in metals and, assuming the unity of mechl anism of these and of aqueous solutions, can be made to give a rationa-explanation for thermal and electrical resistivity, as well as for the thermo-electromotive properties of solutes in solid solutions.

Many other properties of solid solutions will also probably be found capable of explanation by the force-field theory.

[1] On the Relationship of Structure, Density and Chemical Composition of Steel, *Amer. Chemist*, **7**, Nov. 1876, (175–178).

[2] Campbell, E. D., *Amer. Chem. J.*, **18**, 1896, (719–723).

[3] *Zs. physik. Chem.*, **40**, 1902, (545).

[4] Le Chatelier, *Paris, C. R. Acad. Sci.*, **126**, 1898, (1709, 1782).

[5] Baly, E. C. C., *J. Amer. Chem. Soc., Easton, Pa.*, **37**, 1915, (979).

INHERITANCE OF QUANTITY AND QUALITY OF MILK PRODUCTION IN DAIRY CATTLE

By W. E. Castle

Bussey Institution for Research in Applied Biology, Forest Hills, Mass.

Communicated, August 1, 1919

In 1911 the late T. J. Bowlker undertook at his farm in Framingham, Mass., an experimental study of inheritance in dairy cattle by the modern method of crossing pure breeds and looking for a recombination in the second crossbred generation of the characters differentiating the breeds crossed. The breeds which he selected for study were the Holstein-Friesian and the Guernsey, one supreme among dairy breeds in quantity production, the other of very high rank as regards quality of milk produced. It was his belief that if quantity and quality of milk production were independently inherited characters, it should be possible to combine them in a single race by the method of crossbreeding, in accordance with Mendel's law. The desired recombination of qualities, if attainable, would be of much importance to the dairy industry, and at any rate the knowledge whether such recombination is attainable would be a valuable contribution to science. With rare insight into the difficulties surrounding the problem and the proper method of attacking it, Mr. Bowlker planned his experiment on a considerable scale. He had a herd of some 40 pure-bred registered cows, about two-thirds of them being Holsteins, the rest being Guernseys. He also had a pure-bred registered bull of each breed, and in the pedigrees of these bulls excellent blood-lines were represented. He decided to cross-breed the entire herd, mating the Holstein cows to the Guernsey bull and the Guernsey cows to the Holstein bull. In this way what are known as reciprocal crosses were made between the two breeds. In all about 140 F_1 calves were produced between the years 1912 and 1919. As last as the F_1 heifers attained suitable age they were bred to F_1 bulls in order to secure the desired F_2 generation, in which combination of characters might be expected. About 35 living F_2 calves have been produced in this way of which the heifers have been saved for milking tests, for which, however, they are still too young.

Mr. Bowlker did not live to see the completion of his experiment but died in February, 1917. His family undertook to complete the unfinished work, with such scientific advice as I could give them, but practical difficulties having arisen which make it impossible to carry the work

further on the Bowlker farm, arrangements have been made for turning the entire project over to the University of Illinois, where experts in dairying and genetics will study the results in hand and such as may be forthcoming. At the generous suggestion of the new owners of the herd I am making this preliminary statement of results obtained at the Bowlker farm.

Throughout the experiment the herd has been under the same system of management and in charge of the same superintendent, Mr. Leon Haley. The care and feeding have been such as are given to ordinary farm herds and the cows have been milked twice a day. Pure breds and crossbreds have been kept in the same barn and treated alike in every respect. The milk from each cow has been weighed at each milking and these records are now available for study. Occasional butter-fat tests have been made for each cow but these are fewer than could be wished and make it possible only approximately to estimate the total butter fat production of each cow.

Both the F_1 and the F_2 cross-bred calves have proved vigorous and have grown well. Some data have been accumulated on the relative growth-rates of the pure-bred and the cross-bred calves but these are insufficient as yet to lead to any definite conclusions. It should be observed, however, that the F_1 cows have calved for the first time at a slightly earlier age than the cows of either pure breed kept on the farm, a bit of indirect evidence that in vigor and early maturity they conform to the usually high standard of cross-breds. The recorded observations on weight of milk given by pure bred and by F_1 cows and the estimated amounts of butter-fat contained in this milk are summarized in tables 1, 2 and 3. Only data for comparable ages and lactation periods (first and second) are included in the tables. The column 'age' shows the approximate age of the cow at the beginning of the lactation period. The column 'time' shows the duration in months of the lactation period. If no entry is made in this column it will be understood that the lactation period covered a full year. The column 'total pounds milk' shows the amount of milk produced during the twelve months or less of the lactation period. No account is made in this summary of milk produced after the cow had been in lactation for more than twelve months.

Table 2 shows that 25 pure-bred registered Holsteins calving at an average age of 2.8 years gave in their first lactation period an average of 7673 pounds of milk. The amount of butter-fat in the milk can be stated for only 8 of the 25 cows those which were still in the herd when the systematic taking of butter-fat tests for individual cows was undertaken. For these 8 cows the estimated butter-fat percentage is 3.4.

Since this agrees closely with Roberts'[1] finding for the breed in general, it will be assumed to hold for the entire group of 25 cows. On this basis the average butter-fat production for the Holstein cows in their first lactation period would be 261 pounds.

TABLE 1

MILK AND BUTTER-FAT PRODUCTION OF F_1 COWS

COW	FIRST LACTATION PERIOD					SECOND LACTATION PERIOD			
	Age	Time	Total pounds of milk	Fat	Total fat	Age	Time	Total pounds of milk	Total fat
		months		*per cent*			*months*		
*Alice	2⅓		8,070	4.0	323				
Annie	2¾	9	(5,460)	4.3	235	3½		7,536	324
Bessie	3⅓	10	(6,297)	4.0	252				
Blackfoot	2¼		7,755	4.1	318	4⅛		10,125	415
*Daisy	3⅓	11	(7,661)	4.3	329	4⅛		9,375	403
Dora	2¾		7,908	4.2	332	4		11,538	484
Ellen	3⅛	9	(6,096)	4.2	256	4⅛	11½	(8,949)	376
Emerald	2½		8,517	4.1	349				
Emma	2¾	7	(3,768)	4.0	151	3⅜	9½	(7,080)	283
Fairiel	2¼		4,740	4.6	218				
Fanny	2⅝	9	(5,325)	4.0	213	3¾		9,135	365
*Freckles	2⅛		7,773	4.0	311	3⅓		8,340	333
*Grace	3	11	(5,796)	4.3	249				
Inka	2½		7,881	4.3	338				
Jane	2¼		7,809	4.5	351	4⅓	11	(8,646)	389
Julia	2⅝	10½	(6,498)	4.6	279	4		8,835	406
*Kate	2¾		7,689	4.5	346				
Lavaine	2½		5,550	3.7	205				
*Lilvene	3⅛	11	(6,000)	4.1	246				
Lilac	2⅛	11	(7,542)	3.8	286	3⅛		6,489	246
*Mary	2¾		(8,199)	4.0	327	4½	11	(8,871)	355
Nancy	2½		4,899	4.3	210				
Peach	2½		8,508	3.8	323				
Pearl	2½		7,446	3.7	275				
Peggy	2½		6,507	3.8	247				
*Ruby	2½	9	(4,440)	3.7	164				
Sapphire	3⅛		6,618	4.0	264				
Susan	2⅛	10½	(6,168)	4.1	252				
Sylvene	2⅛		6,075	4.0	243				
Tessa	2½	11½	(5,700)	4.4	250	3½		7,710	339
Twisk	2½		6,252	3.8	237				
Average	2.61	11.14	6,612	4.08	270	3.88		8,663	363

In table 3 are summarized the milk production records of 8 pure-bred registered Guernsey cows which also formed a part of the Bowlker herd. They calved for the first time at an average age of 2.7 years and gave in a first lactation period of from seven and one-half to twelve months

an average of 4617 pounds of milk. The recorded butter-fat tests of these cows are too few to form an adequate basis for estimates of their individual butter-fat production. But such tests as were made agree sufficiently well with Roberts' estimate of 5.0% for the breed. On this

TABLE 2

MILK AND BUTTER-FAT PRODUCTION OF PURE-BRED REGISTERED HOLSTEIN COWS

COW	FIRST LACTATION PERIOD					SECOND LACTATION PERIOD			
	Age	Time	Total pounds of milk	Fat	Total fat	Age	Time	Total pounds of milk	Total fat
		months		*per cent*			*months*		
H. S. Clotilde	2 2/3		7,765	3.5	271	3 5/6	10 1/2	(9,803)	343
H. S. Inka	3		9,089	3.4	309	4 1/6	8	(8,866)	301
H. Perfecta Clotilde	3 1/6	9 1/2	(8,030)	3.2	257	4 1/6	11	(10,025)	320
H. S. Judy Colantha	3 1/6		8,875	3.6	319	4 1/2	11	(9,455)	340
H. S. Katharine	2 3/4		8,247	3.2	264	4 1/2	10	(9,263)	296
H. S. Pietertje	2 1/2	9 1/2	(6,887)	3.2	220	3 1/2	9	(8,631)	276
H. S. Twisk	2 1/2	9	(7,701)	3.4	261	3 1/2		10,312	350
H. S. Wachusett	2 1/2	10	(6,481)	3.6	233	3 1/2		10,813	392
H. M. Cre. DeKol	2 3/4	8 1/2	(5,432)		Av. 267	3 5/6	11	(7,619)	Av. 327
H. S. Erie Colantha	2 1/2		6,417			3 1/2		10,470	
H. S. Erie Vernon						3 3/4		10,248	
H. S. V. Julipana	3 1/2		8,582						
H. S. Landor	2 11/12		7,725						
H. M. Segis	2 5/6	9 1/2	(8,900)			3 3/4		10,327	
H. S. Vale Judy	3		10,101						
H. S. Veldoor	3 1/4	10 1/2	(7,445)			4 1/6	10	(9,555)	
H. Cre. Mercedes DeKol	3 1/2	8 1/2	(8,928)			4 1/2	9	(8,186)	
H. M. Judy Colantha	2 3/4		5,493			4 1/6	7 1/2	(6,170)	
H. L. Whetstone DeKol	2 11/12	9 1/2	(5,230)						
H. A. Cre. DeKol	3		7,479			4 1/2	11 1/2	(8,961)	
H. I. Colantha DeKol	2 1/2		7,692			3 3/4	9 1/2	(7,490)	
H. Tessa Netherland	2 5/6		9,699			4 1/2	10 1/2	(9,190)	
H. C. Plum	2 5/6		8,628			4 1/2		11,989	
H. S. Dexter Erie	2 1/2		7,945						
H. Judy Cre. DeKol	3	9 1/2	(7,399)			4	11 1/2	(12,041)	
Average	2.825	11.0	7,673	3.4	261	4.0		9,475	322

basis the average butter-fat production of the 8 Guernseys in their first lactation period would be 231 pounds.

Table 1 shows the observed milk and estimated butter-fat production of 31 F_1 cows which calved at the average age of 2.6 years, one-tenth of a year younger than the Guernseys, two-tenths of a year younger than the Holsteins. They produced an average of 6612 pounds of milk.

This is 1061 pounds less than the average yield of the pure Holsteins, but is 1995 pounds more than the average yield of the pure Guernseys. In other words, the average yield of an F_1 cow exceeds the half-way point between Holsteins and Guernseys by 467 pounds.

As regards butter-fat content of the milk, several different tests have been made of the milk of each F_1 cow and on the basis of these tests rest the estimated percentages given in the table. They indicate an average butter-fat content of 4.08%, which is slightly less than the intermediate between 3.4, the butter-fat percentage of pure Holsteins, and 5.0, the butter-fat percentage of pure Guernseys, for the exact intermediate is 4.2%. But the high quantity production of the F_1 cows more than makes up for the slight deficiency in the quality of their milk, so that

TABLE 3

MILK AND BUTTER-FAT PRODUCTION OF PURE-BRED REGISTERED GUERNSEY COWS

COW	FIRST LACTATION PERIOD			SECOND LACTATION PERIOD		
	Age	Time	Total pounds of milk	Age	Time	Total pounds of milk
		months			*months*	
Hailey All Fawn			5,014	4 1/3	11	(5,558)
H. D. Keepsake	2 3/4	9	(3,825)	3 2/3		7,664
H. D. Lady	3	8	(2,897)	3 5/6		4,852
H. H. Dairymaid	2 5/6		6,942	4 1/12		7,093
Hailey Gloria	2 1/3	11 1/2	(5,548)	3 7/12	11 1/2	(6,084)
H. Modena Maid	3	11 1/2	(6,060)	4	8 1/2	(3,983)
Rockbottom Keepsake	2 5/12	9	(4,529)	3 1/2	10 1/2	(4,209)
Rockbottom Leading Lady	2 5/12	7 1/2	(2,121)	3 1/2	10 1/2	(5,307)
Average	2.72	10.0	4,617	3.79		5,593

the average total butter-fat production of each cow is 270.2 pounds, which is 9 pounds more than the average butter-fat production of the pure Holsteins, and 40 pounds more than the estimated butter-fat production of the pure Guernseys. Accordingly on the basis of the records for their first lactation period the F_1 cows seem to surpass either pure breed in butter-fat production and to be better than an intermediate between the pure breeds as regards quantity of milk produced.

A second lactation period has been completed by 13 of the 31 F_1 cows listed in table 1. They of course produce more milk in the second lactation period than in the first, and so comparison should be made with the second lactation period of pure-bred Holsteins and Guernseys, data for which are given in tables 2 and 3. Roberts[1] has shown that the butter-fat percentage of a cow's milk does not change materially with age, so

that we assume it to be for each cow the same in the second lactation period as in the first.

Table 2 shows that 20 pure-bred Holsteins of average age 4.0 years, when the second calf was born, produced an average of 9475 pounds of milk in the second lactation period. Table 3 shows that 8 pure-bred Guernseys of average age 3.8 years when the second calf was born, produced an average of 5593 pounds of milk in the second lactation period. Table 1 shows that the 13 F_1 cows being of average age 3.9 years when the second calf was born, produced an average of 8663 pounds of milk in their second lactation period. This is 812 pounds less than the average production of the pure Holsteins, but is 3070 pounds more than the average production of the pure Guernseys and *exceeds the intermediate between the pure breeds* by 1129 pounds. The deviation is of the same sort as in the first lactation period but is even more striking. As regards quantity production it is clear that the F_1 cows are better than an intermediate between the breeds crossed.

In butter-fat production, using the same percentage estimates as were used for the first lactation period, the Holsteins average 322 pounds, the Guernseys 280 pounds, and the F_1 cows 363 pounds, an excess for the F_1 cows of 41 pounds over the pure Holsteins and of 83 pounds over the pure Guernseys. Again the F_1 cows show superiority over either pure breed in butter-fat production, while in quantity production of milk they are nearer to pure Holsteins than to an intermediate between the pure breeds.

This result is comparable with that observed in the inheritance of size and other quantitative characters both in animals and in plants. In such cases F_1 usually surpasses more or less the intermediate between the races crossed owing to the superior vigor commonly possessed by cross-bred organisms. But F_2 usually varies about a strict intermediate between the races crossed and such we may anticipate will probably be the outcome in this case unless quantity production and quality production to some extent depend on different genetic factors, the point which Mr. Bowlker set out to investigate. If independent genetic factors are really concerned in quantity production and in quality production respectively, their recombination in F_2 may be expected in animals which are both high producers and which give rich milk and such animals should be capable of transmitting this desirable combination of characters to their descendants. Such a result would realize Mr. Bowlker's fondest hopes, and would open great possibilities for the systematic improvement of dairy cattle.

A word should be said as to the theoretically important question whether the reciprocal crosses differ in their results. No consistent difference is observable. Eight of the 31 F_1 cows (indicated by an asterisk in table 1) had Guernsey dams while 23 had Holstein dams. In their first lactation period the cows with Guernsey dams gave less milk but more butter-fat, average 6953 pounds of milk, 287 pounds of butter-fat. But in the second lactation period, three cows with Guernsey dams give a little more than the average amount of milk with exactly the average amount of butter-fat. It seems unlikely, therefore, that any sex-linked factors are concerned in the case.

[1] Roberts, Elmer. Correlation between the percentage of fat in cow's milk and the yield. *J. Agric. Res.*, **14**, No. 2, July 8, 1918.

STUDIES OF MAGNITUDES IN STAR CLUSTERS, X. SPECTRAL TYPE B AND THE LOCAL STELLAR SYSTEM

By Harlow Shapley

Mount Wilson Observatory, Carnegie Institution of Washington

Communicated by G. E. Hale, August 26, 1919

In an earlier communication[1] it has been suggested that the properties of star-streaming and the observed decrease of stellar density with increasing distance from the sun, as well as other observational phenomena, can be explained if the sun is shown to be not far from the center of a large physically-organized star cluster or cloud, which is imbedded in a typical stellar region of the galactic system. Evidence of the existence of such a local group, intermingled with stars of the galactic field, was found from various sources; in particular, the distribution of the brighter stars of spectral type B directly supported the hypothesis that a much flattened local system, of limited extent, surrounds the sun asymetrically, with its equatorial plane inclined some 12 degrees to the plane of the Milky Way.[2] Until recently we have commonly supposed that this stellar assemblage, which is now called the local cluster, constitutes the major part of the known sidereal system; at present we hold it to be a very minor part of the galactic organization.

The completion at the Harvard College Observatory of the first three volumes of the *Henry Draper Catalogue* of stellar spectra permits examination of the distribution of the fainter B-type stars as a graphical test of the existence, dimensions, and inclination of the local system. Miss Cannon has kindly supplied the proof sheets of the third volume of the catalogue in advance of publication. The region covered by

these three volumes is that most important for the present problem, since the spectra of all B stars (down to magnitude 8 or 8.5 and many fainter ones) from zero to nine hours in right ascension are included, and in the later hours of right ascension the stars of the Milky Way and those of the local cluster are much less clearly separated on the face of the sky. This difference in separation in opposite hemispheres results from the fact that the sun is some distance to one side of the central plane of the local cluster, thus giving a conspicuous 'dip' to the encircling inclined belt of cluster stars, which minimizes the separation from the galactic equator in Scorpio and Ophiuchus and exaggerates it the most in Taurus and Orion.

The amount of the apparent separation from the Milky Way for any given galactic longitude naturally depends on the average distance (brightness) of the cluster stars concerned. For those not more than 200 parsecs distant from the sun, the maximum separation from the galactic equator is about 17° in Orion and Taurus, as indicated by the broken curve in all the accompanying figures. For stars at the distance of 400 parsecs, which appears to approximate the equatorial radius of the cluster, the maximum separation is a little less than 14 degrees, as shown by the lightly dotted curve in figure 2.

Right ascension and declination are rectangular coordinates in figure 1, which shows the course of the Milky Way throughout the first thirteen hours of right ascension. The data are taken from *Harvard Annals*, **50**, which was the chief source of information regarding stellar spectra before the appearance of the *Henry Draper Catalogue*. Each plotted point in figure 1 shows the position of a star of spectral type B (the subdivisions B8 and B9 are not classed with the other B's—a customary procedure in statistical discussions of spectra). The full curve represents the galactic equator, that is, the central line of the Milky Way after correction for the small dip due to the sun's position slightly to the north of the galactic plane. The broken curve shows the projection of the plane of the local cluster. The determination of this curve was based upon stars brighter than magnitude 5.5 (*Mt. Wilson Contr.*, No. 157, p. 21); if the stars to the sixth magnitude, as plotted in figure 1, had been used in the computation, it is very probable that the curve would be slightly nearer to the galactic equator.

It is clear at once from figure 1, that these B-type stars are affiliated with the local cluster. We may reasonably assume that about twenty of them, along the galactic plane, may be actual members of the galactic field, and that the other three hundred are members of the subordinate local system, quite unrelated to the plane of the Milky Way. On the

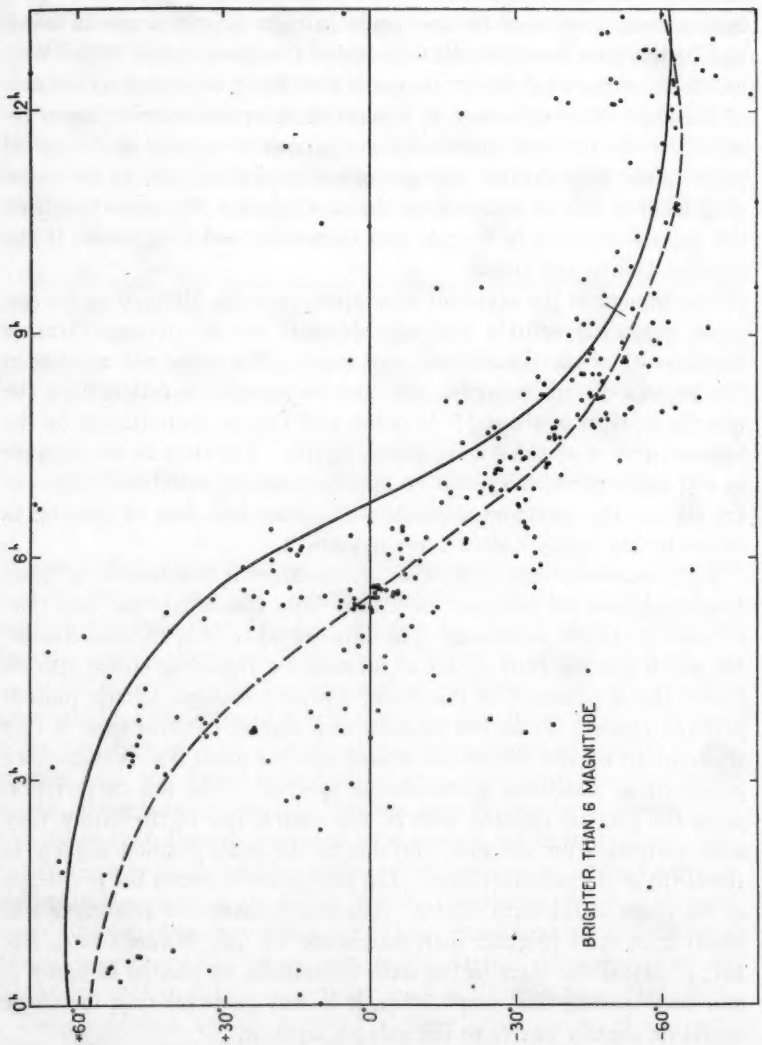


Fig. 1. Distribution of B0–B5 stars, from *Harvard Annals, 50.* In all three figures ordinates are declination, abscissæ are right-ascension. The curves are described in the text.

east side of the Milky Way (in the part of the sky under consideration) there are scarcely any bright B-type stars; on the west there are hundreds of them. The remarkable inequality gives rise to what was called, in an earlier paper, the 'Secondary Galaxy.' This sub-ordinate Milky

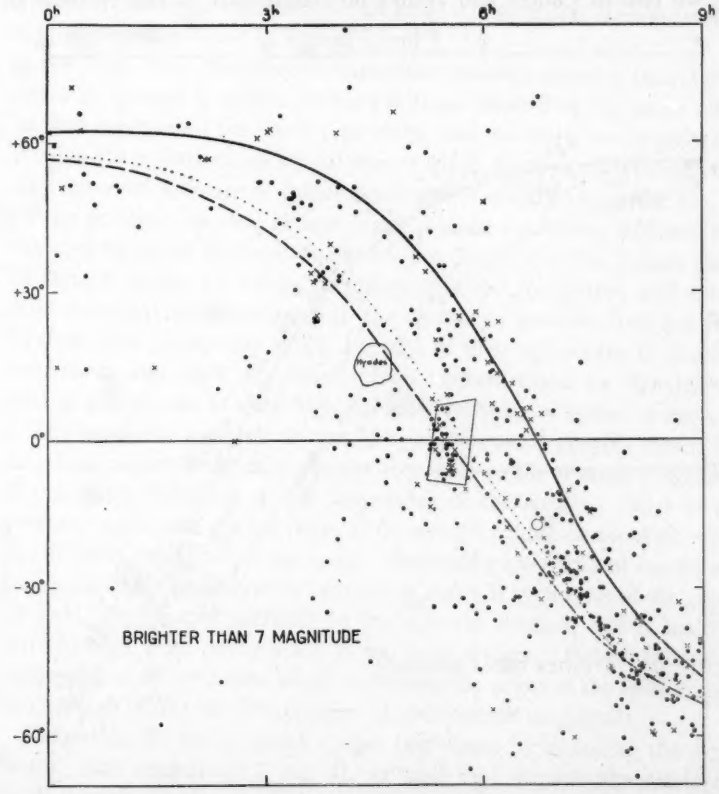


Fig. 2. Distribution of bright B stars, from the *Henry Draper Catalogue*. Crosses refer to sub-types B0, B1, and B2 (and undefined B's); the dots refer to sub-types B3 and B5. The curves are described in the text. The large circle shows the position of Sirius; the trapezoid indicates the constellation Orion. The direction of the center of the local cluster falls near the lower right-hand corner of the diagram.

Way, though well defined by star analyses throughout its complete circuit of the sky, to the naked eye is most clearly seen in the region mapped in figure 1, where it stands out some 10 to 20 degrees along the west side of the Milky Way from Perseus southward through Taurus, Orion, and Canis Major to Puppis and Carina. Not only the very

bright stars of types B and A throughout this region may be assigned to the cluster, but also the rich belt of stars of all types with magnitudes from three to seven. Across from Orion and Canis Major, on the other side of the Milky Way and at the same distance from the galactic equator, we find in Cancer and Hydra no counterpart of this richness in

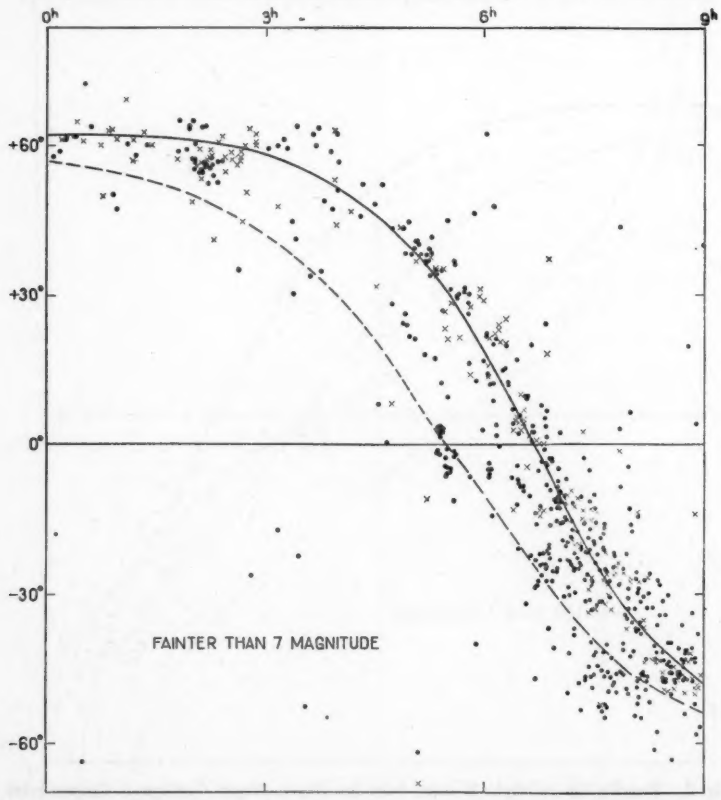


Fig. 3. Distribution of faint B stars, from the *Henry Draper Catalogue*. The wide extent of the bright double cluster in Perseus is shown by the points near declination + 60° and right ascension 2^h.

naked-eye stars; and the intervening constellation Monoceros is almost destitute of stars brighter than the sixth magnitude, although it lies along the central line of the Milky Way and is surpassingly bright in telescopic stars of the far-extending galactic segment.

From the recent studies by Walkey, Charlier, and Strömberg it is known that the center of the stellar system that immediately surrounds

the sun is in the general direction of the constellation Carina. The approximate galactic longitude of this center (which is to be taken as the center of the local cluster rather than that of the galactic system) is indicated in figure 1 by the short line across the galactic equator. A greater frequency of stars is to be noted in this direction, especially of the fainter objects plotted in figures 2 and 3.

We recall that Strömberg's researches,[8] through showing that stars of types F, G, and K appear to have motions related to the same center as that determined for the B-type stars, may be taken as strongly supporting the hypothesis of a local cluster which involves all types of stars. The observed decrease of stellar density with distance from the sun, for all the principal spectral classes, is also almost conclusive evidence that the phenomena of the local cluster are not confined to the B stars alone. It appears highly probable, therefore, that the inclination and extent now under investigation refer to the cluster as a whole, and not only to these blue giant stars which, because of their uniformity in absolute brightness and their apparently high concentration to dynamically central planes, are of such high value in outlining a stellar system.

The available volumes of the new catalogue of spectra cover less area than shown in figure 1, but the extension to the seventh magnitude (fig. 2) adds definitely to our knowledge of the cluster. Stars of the seventh magnitude are 1.6 times as far away as those of the sixth when the intrinsic brightness is the same. Increasing the depth of our survey by that amount has therefore brought in many B-type stars of the galactic field, objects concentrated to the galactic equator, and it has not introduced a great many stars of the local system. Hence, there is a suggestion in figure 2 that we are attaining the edges of the local cluster when we go out to the B-type stars of the seventh magnitude.

Extending the survey much deeper into space by including the stars fainter than magnitude 7 (fig. 3), we find that outside the relatively small domain of the local cluster the galactic equator has definitely established itself as the central circle for B-type stars.

The very high concentration of these distant stars to the Milky Way is a striking illustration of the great depth of the galactic system when compared with its extent perpendicular to the galactic plane. Probably the most important inference from figures 2 and 3 is, however, that the galactic field is continuous in the immediate environs of the local cluster—that the latter is not a large group or cloud distinctly and distantly isolated in space from other stellar regions. Similar evidence of a surrounding and intermingling galactic field may be deduced from the distribution of Cepheid variables, N-type stars, planetary nebulae, and similar special classes of sidereal objects.

In figures 2 and 3 the crosses indicate the position of stars of the sub-types B0, B1, and B2, and the dots refer to the sub-types B3 and B5. Stars of the first group of sub-types are believed to be intrinsically brighter than those of the second. For a given apparent magnitude, therefore, their distances are greater—possibly even twice as great. It is to be noted that the crosses have completely left the secondary circle in figure 3, indicating that the local cluster is not large enough to include objects as distant as B1 stars must be when they appear fainter than magnitude 7.

[1] Shapley, Harlow, these PROCEEDINGS, 4, 1918, (224–229); *Mt. Wilson Communications*, No. 54. See also *Mt. Wilson Contr.*, No. 157, and a small modification of the original statement of a star-streaming hypothesis, *Mt. Wilson Contr.*, No. 161, section IX.

[2] For other properties of the local cluster and for a discussion of the peculiar value of B-type stars in describing its extent, form, and orientation, reference may be made to *Mt. Wilson Contr.*, No. 157, part II. and No. 161, section IX.

[3] Strömberg, Gustaf, *Astrophys. J., Chicago, Ill.*, 47, 1918, (7–37); *Mt. Wilson Contr.*, No. 144.

INFLUENCE OF IONS ON THE ELECTRIFICATION AND RATE OF DIFFUSION OF WATER THROUGH MEMBRANES

BY JACQUES LOEB

THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, NEW YORK

Communicated, August 27, 1919

1. When pure water is separated from a watery solution by a strictly semipermeable membrane more molecules of water will diffuse through the membrane from the pure solvent to the solution than will diffuse simultaneously in the opposite direction; and this difference in the rate of diffusion of water in the two opposite directions will be the greater the higher the concentration of the solution. When the solution is put under pressure, the number of molecules of water diffusing in the unit of time from the solution into the pure solvent will be increased and if this pressure reaches a certain value the number of molecules of water diffusing simultaneously in opposite directions through the membrane will become equal. We may therefore define the osmotic pressure of the solution as the additional pressure which has to be applied to the solution in order to cause as many molecules of water to diffuse from the solution to the pure solvent as will diffuse simultaneously in the opposite direction.

van't Hoff's theory of osmotic pressure assumes that this quantity depends exclusively upon the concentration of the solution. For some

time it had been known that in certain cases water is able to diffuse from solutions of higher to solutions of lower concentrations, and it has been suggested by a number of authors, e.g., Girard,[1] Bartell,[2] Bernstein,[3] and others that these phenomena are due to electrical forces caused by the presence of electrolytes in solution. They assume on the basis of the experimental and theoretical work done by Quincke, Helmholtz, Perrin,[4] and others on electrical endosmose that differences of electrical potential on both sides of the membrane influence the rate of diffusion of water through the membrane.

The writer has recently investigated the influence of electrolytes on the rate of diffusion of water through collodion bags prepared in a definite and uniform way and bathed over night in a 1 per cent gelatin solution. The bags had the shape of Erlenmeyer flasks with 50 cc. contents and were closed by rubber stoppers which were perforated by a glass tube with a bore of 2 mm., the tube serving as a manometer.

When such a bag was filled with watery solution and was dipped into distilled water the level of the water in the manometer rose owing to the fact that more water diffused from the pure water into the solution than diffused simultaneously in the opposite direction, as was to be expected. It was found that the initial rate of diffusion of water was influenced in an entirely different way by electrolytes and non-electrolytes. The solutions of non-electrolytes, e.g., sugars, influenced the initial rate of diffusion of water through the membrane in proportion to their concentration and this influence began to show itself when the concentration of the sugar was above M/64 or M/32. Sugar solutions of lower concentrations than M/64 caused no rise in the manometer. We will call this effect of the concentration of the solute on the initial rate of diffusion the gas pressure effect. Solutions of electrolytes show this gas pressure effect also, but it commences at somewhat higher concentrations than M/64, namely at M/16 or even M/8. Solutions of electrolytes of a lower concentration than M/16 or M/8 have a specific influence on the rate of diffusion of water through the membrane which is not found in the case of non-electrolytes.

When we separate a watery solution of an electrolyte of a concentration below M/16 from pure water by a collodion membrane, the water molecules diffuse through the membrane as if they were electrically charged—positively or negatively according to the nature of the ions present—and as if they were attracted electrostatically by ions of one sign and repelled by ions of the opposite sign. When we used solutions of electrolytes theoretically isosmotic with a M/64 cane sugar solution

it was found that the influence of the nature of the electrolytes on the rate of diffusion of water through a collodion membrane could be expressed in the following two rules:

(1) Neutral solutions of salts possessing a univalent or a bivalent cation influence the rate of diffusion of water through a collodion membrane as if the water particles were charged positively and were attracted by the anion and repelled by the cation of the electrolytes; the attractive and repulsive action increasing with the number of charges of the ion and diminishing inversely with a quantity which we will designate arbitrarily as the 'radius' of the ion. The same rule applies to solutions of alkalies.

(2) Solutions of neutral or acid salts possessing a trivalent or tetravalent cation influence the rate of diffusion of water through a collodion membrane as if the particles of water were charged negatively and were attracted by the cation and repelled by the anion of the electrolyte. Solutions of acids and of neutral salts with monovalent or bivalent cation when rendered sufficiently acid obey the same rule.[5]

Thus the rate of diffusion of water into a neutral solution was considerably greater when the solution was M/128 NaCl than when it was M/64 cane sugar; and when different sodium or potassium salts were compared it was found that the rate increased with the valency of the anion of the salt in solution, sulfates and oxalates acting more powerfully than chlorides and nitrates, and citrates and ferrosulfocyanides more powerfully than sulfates and oxalates. The rate of diffusion of water was less when the solution was M/192 $CaCl_2$ than when it was M/64 cane sugar, and the same was true for all solutions of neutral salts with bivalent cation and monovalent anion. The attraction of M/128 solutions for water increased in the order $Li < Na < K$, showing the influence of the 'radius of the ion.' Solutions of alkalies like NaOH or KOH acted similarly to solutions of NaCl or KCl. All this was to be expected if water particles behaved as if they were positively charged, being attracted by the anion and repelled by the cation of the electrolyte.

In the case of electrolytes falling under rule 2, water particles behave as if they were negatively charged and attracted by the cation and repelled by the anion of the electrolyte with a force increasing with the number of charges of the ions. Thus solutions of Al_2Cl_6 attract water very powerfully, solutions of $Al_2(SO_4)_3$ of the same theoretical concentration act much more feebly and solutions of aluminum citrate have practically no more influence on the rate of diffusion of water than cane sugar solutions of the same concentration. When we render M/128 so-

lutions of NaCl acid (by dissolving the salt in M/1024 HCl) the water particles diffusing through the membrane are negatively charged and are attracted by the Na ion of the solution. This is supported by the fact that M/192 $CaCl_2$ dissolved in M/1024 HCl (or HNO_3) attracts water much more powerfully than does M/128 NaCl of the same hydrogen ion concentration; and the attraction of M/512 Al_2Cl_6 of the same hydrogen ion concentration for water is still more powerful than that of $CaCl_2$. All this is intelligible on the assumption of an electrostatic influence of the ions upon negatively electrified particles of water—no matter what the nature or source of electrification of water may be. That water is indeed electrified in the sense expressed in the two rules was proved directly by experiments on electrical endosmose.

The collodion membranes are not only permeable to water but also to crystalloids in solutions. It could be shown by analytical experiments that the phenomena expressed in the two rules were not due to differences in the rate of diffusion of the solute. The reader will find a full description of these experiments in a recently published paper.[6]

3. The two rules mentioned before were based on experiments with solutions of about the same gas pressure, namely that of a M/64 sugar solution. When we compare the osmotic effect of different concentrations of sodium (or Li, K, NH_4) salts within the limit of M/8192 to about M/16 we find a curious phenomenon. In these experiments the solution of the electrolyte was put inside the collodion bag and the latter was dipped into a beaker with pure water. It was found that under these conditions the initial rise (i.e., the rise in the first ten or twenty minutes) of water in the collodion bag increased rapidly with the increase of the concentration of the solution, this initial rise reaching a maximum when the concentration of the electrolyte was about M/256. With a further increase of the concentration of the electrolyte the initial rate of diffusion of water from pure solvent into the solution dropped rapidly, reaching a minimum at about a concentration of M/16. We therefore notice the paradoxical fact that M/256 solutions of all these electrolytes attract water more powerfully than M/16 solutions of the same electrolytes. Thus in the case of a neutral solution of sodium oxalate the level of water rose in the manometer of the flask in twenty minutes to about 100 mm. when the concentration of the solution was M/1024, to 220 mm. when the concentration was M/256, but only to 100 mm. again when the concentration was M/16. While I do not wish to make any assumption concerning the source of the electrification of water and the mechanism by which

the electrolytes influence the rate of diffusion of water through a membrane it will simplify the presentation of my results if it is permitted to ascribe them to the attraction and repulsion of the charged particles of water by the ions. With this reservation we may say that the rise in the first part of the curve, in concentrations from 0 to about M/256, being caused by the prevalence of the attractive action of the anion upon the negatively charged particles of water, while the drop in the curve, when the concentration increases beyond M/256, is due to the fact that with a further increase in the concentration the repelling effect of the Na ion upon the water particles increases more rapidly than the attractive effect of the oxalate anion. With concentrations above M/16 or M/8 the gas pressure effect of the solution commences to prevail over the electrostatic effects of the ions and the rate of diffusion of water rises again with increasing concentration.

We may state incidentally that all these phenomena can be observed just as well in collodion membranes which have not been treated with gelatin, so that the gelatin plays no rôle in the action of the membrane on solutions of neutral or alkaline salts.

4. This influence of the concentration of electrolytes upon the rate of diffusion of water explains the phenomenon of negative osmosis. It had been known for more than fifty years through the experiments of Dutrochet and Graham which were recently confirmed by Flusin,[6] that solutions of certain acids, like tartaric and oxalic, when separated from pure water by a membrane of pig's bladder produce a negative osmosis, i.e., water diffuses from the solution to the pure solvent. This is, of course, exactly the reverse of what one should expect on the basis of van't Hoff's theory. The writer has investigated this phenomenon and he found that it holds with certain exceptions for all the acids and all the alkalies, *and that this expulsion of water from the solution (the so-called negative osmosis) occurs in exactly the same range of concentrations where the drop in the electrostatic attraction of sodium salts for water occurs, namely in concentrations from about M/256 to about M/8.* Collodion flasks were filled with distilled water and submersed in beakers filled with solutions of acids or alkalies of different concentrations. The volume of water in the flask instead of diminishing increased when the concentration of the acid was between M/256 and M/16 or M/8 and the increase was the more considerable the higher the concentration of the acid or alkali within the limits mentioned.

Our first rule states that in the presence of salts and alkalies with univalent and bivalent cation water diffuses through the collodion mem-

brane as if its particles were positively charged. On the basis of this statement the initial expulsion of water by solutions of alkalies in concentrations above M/256 should be due to the fact that above a concentration of M/256 the repelling action of the cation upon the positively charged water particle increases more raipdly with increasing concentration of the elctrolyte than the attractive action of OH ions. When the cation is bivalent, e.g., when we use $Ca(OH)_2$ or $Ba(OH)_2$ as alkalies, the repelling action of the Ca and Ba ion with their two charges is so much stronger than the weak attractive action of the OH ions that water diffuses more rapidly from solution into pure water than pure water can diffuse into the solution, and the level of the water rises (during the first twenty minutes or more) in the pure solvent and falls in the solution. It harmonizes with our suggestion that the negative osmosis does not exist in the case of alkalies with monovalent cation like NaOH or KOH.

If the solution is an acid, water diffuses through the membrane as if its particles were negatively charged, being attracted by the H ion and repelled by the anion of the acid. In concentrations of acid of M/256 to about M/8 the solution expels during the first twenty minutes water into the pure solvent and the more the higher the concentration. This negative osmosis should be due to the fact that within this range the repelling action of the anion of the acid upon negatively charged water particles increases more rapidly with the concentration than the attractive action of hydrogen ion.

This suggestion is supported by the fact that the rate in which the acid solution expels water increases for the strong acids with the valency of the anion. Thus the amount of negative osmosis is small or negligible in the case of HCl or HNO_3, is considerable in the case of H_2SO_4 and oxalic acid, and still greater in the case of H_3PO_4. The phenomenon is not noticeable in the slightly dissociated acetic acid.

5. The definition of osmotic pressure as given in the introduction of this paper suggests that in the case of strictly semipermeable membranes the permanent osmotic pressure of the solution should show a simple relation to the difference in the initial rate of the diffusion of water in the two opposite directions through a membrane. Our experiments have shown that the initial rate of diffusion of water through a collodion membrane is determined for lower concentrations of electrolytes to a large extent by the electrostatic effects of the ions present and we should expect that these electrostatic effects would also influence the permanent osmotic pressure of solutions of electrolytes. Collodion membranes which are

permeable for solutions of crystalloids are impermeable for solutions of colloidal salts, e.g., the salts of gelatin. It can be shown that the permanent osmotic pressure of solutions of gelatin salts is influenced by the electrostatic action of ions in a similar way as is the rate of diffusion of water. I have found that water diffuses into neutral solutions of Na, K, Ca or Ba gelatinate as if the particles of water were positively charged. Since Ca and Ba (and all the other bivalent cations) have a greater repelling effect on positively charged particles of water than Li, Na, K or NH_4, the initial rate of diffusion of water should be greater when gelatin (in a 1% solution) is in combination with a monovalent cation than when it is in combination with a bivalent cation. I have tested this idea and found it confirmed. When we separate 1% gelatin solutions from distilled water by a collodion membrane the initial rate of diffusion of water into the solution is a little over twice as great when the gelatin exists in the form of sodium gelatinate than when it exists as calcium gelatinate, both having the same hydrogen ion concentration. The permanent osmotic pressures of the two types of solutions show also approximately the same ratio, being about or a little over twice as great in the case of sodium gelatinate as in the case of calcium gelatinate of the same concentration of gelatin as well as of hydrogen ions. Li, K, and NH_4 gelatinate behave like sodium gelatinate while Mg, Sr, and Ba gelatinate behave like calcium gelatinate.

Water particles behave like negatively charged particles in the presence of gelatin salts in which the gelatin is a cation, e.g., gelatin chloride or gelatin sulfate. If 1% solutions of these two gelatin salts of the same hydrogen ion concentration are prepared and put into collodion bags, water diffuses twice as rapidly into the gelatin chloride solution as into the gelatin sulfate solution. The osmotic pressures of the two solutions vary also as about 1:2 or a little less.[7]

The full report of the experiments on the influence of the concentration of electrolytes on the electrification and rate of diffusion of water through membranes will appear in the *Journal of General Physiology*.

[1] Girard, P., *Paris, C. R. Acad. Sci.*, 146, 1908, (927); 148, 1909, (1047–1186); 150, 1910, (1446); 153, 1911, (401); La pression osmotique et le mechanisme de l'osmose, *Publications de la Société de Chimie-physique*, Paris, 1912.

[2] Bartell, F. E., *J. Amer. Chem. Soc.*, 36, 1914, (646). Bartell, F. E., and Hocker, C. D., *Ibid.*, 38, 1916, (1029–1036).

[3] Bernstein, J., *Elektrobiologie*, 1912.

[4] Perrin, J., *J. Chem. Physique*, 2, 1904, (601); 3, 1905, (50).

[5] Loeb, J., *J. Gen. Physiol.*, 1, 1918–19, (717).

[6] Flusin, G., *Ann. chim. phys.*, 13, 1908, (480).

[7] Loeb, J., *J. Gen. Physiol.*, 2, 1919, No. 1.

NATIONAL RESEARCH COUNCIL

MEETING OF THE INTERIM COMMITTEE

AT THE NATIONAL RESEARCH COUNCIL BUILDING, MAY 20, 1919, AT 9.30 A.M.

Present: Messrs. Bancroft, Hussey, Leuschner, Mathews, Merriam, Washburn, and Woods.

Mr. Merriam, Chairman of the Council, in the Chair.

The minutes of the meetings of the Interim Committee of April 22 and April 28 were approved as circulated.*

In behalf of the committee consisting of Messrs. Walcott (Chairman), Cross, Dunn, and Merriam, appointed May 8 to carry out plans and to make arrangements to move the offices of the National Research Council to more suitable quarters, the Chairman reported favorably on the availability of the Navy League Building.

Moved: That if the Navy League Building be leased for the use of the National Research Council a committee of three be appointed to consider apportionment of space for the departments of the Council. (*Adopted.*)

Appointed: Messrs. Yerkes (Chairman), Leuschner, and Mathews. At the request of Mr. Yerkes, Mr. Mathews was subsequently designated as chairman of the committee.

Moved: That Mr. H. O. Wood be appointed Assistant to the Secretary of the National Research Council from May 16, 1919, to June 30, 1919. (*Adopted.*)

Moved: That Mr. Albert L. Barrows the recently appointed Secretary of the Divisions of States Relations and Educational Relations of the National Research Council, be authorized to stop on his way to Washington from California to consult with a number of state scientific committees and with research committees in educational institutions. (*Adopted.*)

Mr. Yerkes, as Chairman of the Committee on Organization of the Government Division, consisting of Messrs. Bancroft, Nichols, and Yerkes presented a report which was provisionally approved and later, May 27 and June 17, adopted by the Executive Board and the Council of the National Academy of Sciences in the following form:

Organization of the Government Division

1. The Division shall consist initially of

(a) a representative of each of the following bureaus with the provision that other bureaus may be added:

* The Interim Committee has power to act between meetings of the Executive Board. Heretofore its actions have been reported as part of the next following meeting of the Executive Board.

Department of State
Foreign Intelligence Division
Department of the Treasury
Public Health Service
Department of War
General Staff Corps
Military Intelligence Division
Surgeon General's Office
Corps of Engineers
Ordnance Department
Signal Corps
Coast Artillery Corps
Air Service
Chemical Warfare Service
Department of Justice
Division of Investigations
Post Office Department
Department of the Navy
(Office of Naval Operations)
Office of Naval Intelligence
Bureau of Navigation
Naval Observatory
Bureau of Ordnance
Bureau of Construction and Repair
Bureau of Steam Engineering
Bureau of Medicine and Surgery
Department of the Interior
Patent Office
Bureau of Education
Geological Survey
Reclamation Service
Bureau of Mines
Department of Agriculture
Weather Bureau
Bureau of Animal Industry
Bureau of Plant Industry
Forest Service
Bureau of Chemistry
Bureau of Soils
Bureau of Entomology
Bureau of Biological Survey
Office of Public Roads and Rural Engineering
Department of Commerce
Bureau of the Census
Bureau of Standards
Bureau of Fisheries
Coast and Geodetic Survey
Department of Labor
Information and Education Service
and the
Smithsonian Institution

(b) the Chairman of the Research Information Service who shall serve as Secretary of the Division.

2. That the name of a suitable representative of each of the foregoing bureaus be presented to the President of the United States in accordance with Article V, Section 3, of the Organization of the National Research Council, for designation by him for service with the National Research Council on the Government Division.

3. That the President of the United States be asked to designate Heads of Government Divisions, or suitable representatives thereof, to be appointed as members of the National Research Council and assigned to the Government Divisions.

4. That the Government Division be represented on each Division of Science and Technology by one member.

5. That this official representative of the Government to serve on a Division of Science and Technology be nominated by the Executive Committee of the Government Division in conference with the Executive Committee of the Division of Science and Technology on which he is to serve.

6. That further desirable cooperative relations between the Division of Government Relations and the several Divisions of Science and Technology be established through Article III, Section 6, of the new organization.

Mr. Yerkes presented the following nominations of representatives of Government Departments for membership on the Research Information Service:

Labor Department, Royal Meeker
Agriculture Department, Carl L. Alsberg
Commerce Department, S. W. Stratton
Interior Department, Van H. Manning
War Department, Major General Marlborough Churchill
Navy Department, Rear Admiral Albert P. Niblack
State Department, Wesley C. Frost
Treasury Department, J. W. Schereschewsky

Moved: That the names of the foregoing representatives of government departments be presented to the President of the United States in accordance with Article V, Section 3, of the Organization of the National Research Council, for designation by him for service with the National Research Council on the Research Information Service. (*Adopted.*)

On further recommendation of Mr. Yerkes, it was

Moved: That Dr. Milton J. Greenman, of the Wistar Institute of Anatomy and Biology of Philadelphia, be elected a member at large of the Research Information Service with the recommendation to the President of the National Academy of Sciences that he be appointed a member of the National Research Council and assigned to the Research Information Service. (*Adopted.*)

Mr. Leuschner, the Acting Chairman of the Division of Physical Sciences presented the following committees for approval:

Committee of five consisting of Messrs Millikan, Moore, Moulton, Slaught, and Dickson (Chairman) to consider the proposal of a Mathematical Dictionary and report to the Executive Committee of the Division.

Committee of three consisting of Messrs. Leuschner (Chairman), Bumstead, and Fulcher to make recommendations regarding abstracts, bibliographies, and monographs.

Mr. Leuschner, the Acting Chairman of the Division of Physical Sciences reported that in accordance with action taken by the Executive Board of the Council on April 15, 1919, which provides for a joint committee of the Divisions of Chemistry and Chemical Technology and of Physical Sciences on a plan for the publication of critical tables of physical and chemical constants, Messrs. Bumstead and Millikan had been nominated by the Division to serve on the joint committee. (*Approved*)

On recommendation of the Acting Chairman of the Division of Physical Sciences, it was further

Moved: That the Division of Educational Relations be requested to coöperate with the Division of Physical Sciences and that of Chemistry and Chemical Technology, in formulating proper plans whereby a research survey in Physics and Chemistry might be made in educational institutions and report back to the Division. (*Adopted.*)

Moved: That the principle of appointing committees for the organization and stimulation of research in various subjects of physics be approved, with the provision that each member of the division become responsible for one or more subjects, which he shall choose in consultation with the Acting Chairman of the Division. (*Adopted.*)

Moved: That Mr. H. O. Wood be appointed Acting Secretary of the American Section of the proposed International Geophysical Union. (*Adopted.*)

On recommendation of the Chairman of the Council it was

Moved: That the Chairman of the Research Fellowship Board be a member of the Division of Educational Relations. (*Adopted.*)

Mr. Washburn, the Acting Chairman of the Division of Chemistry and Chemical Technology presented the following recommendations:

That a Committee on Sewage Disposal be formed to undertake the following projects:

1. To prepare a research survey of the field with special reference to possible methods of sewage disposal which will recover the valuable oils, fats, and fertilizer constituents of the sewage; this survey to include statistical data and a discussion of the economic aspects of the subject as well as the scientific ones.

2. To outline a series of basic research problems necessary to the further extension of our knowledge of the possibilities of recovering and utilizing the valuable constituents of sewage.

3. To ascertain what researches are already in progress in the country in connection with this problem, and if it seems desirable, to prepare a list of sewage experiment stations or similar organizations whose equipment and staffs may possibly be utilized in connection with any project of coöperative research which it seems wise to undertake.

4. To prepare general plans and estimates of cost of establishing a sewage experiment station to study new methods of treating sewage for the recovery of its valuable constituents and to work in close coöperation with investigators now engaged or who in the future may be interested in undertaking physical, chemical, or bio-chemical investigations on various aspects of the problems which present themselves.

5. To investigate particularly the Rice Process and the Miles Process of sewage treatment and to make recommendations to the Division as to what action, if any, the Council might take with reference to research or development in connection with one or both of these processes. (*Adopted.*)

That the Committee on Sewage Disposal be constituted with the following personnel:

Professor G. C. Whipple, Professor of Sanitary Engineering, Harvard University, Chairman.

Major C. G. Hyde, (Professor of Sanitary Engineering, University of California) Surgeon General's Office, War Department, Washington, D. C.

Lt.-Col. Edward Bartow, Sanitary Corps, U. S. A., A. E. F. Water Analysis Laboratory, U. S. A. P. O. No. 702 (?) (Chief of the Illinois State Water Survey and Professor of Sanitary Chemistry, University of Illinois.)

Lt.-Col. W. D. Bancroft, (Chairman Division of Chemistry and Chemical Technology, National Research Council), American University Experiment Station Washington, D. C.

Professor E. B. Phelps, care of Dr. Charles North, 30 Church Street, New York.

Mr Martin H. Ottner, 105 Judson St., Jersey City, N. J.

Dr. W. W. Garner, Physiologist, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C. (*Adopted.*)

That the title of the Committee on Specific Heats of Explosive Materials, authorized at the meeting of April 21, be changed to the Committee on the Thermal Properties of Explosive Materials. (*Adopted.*)

That the Chairman of the Division of Chemistry and Chemical Technology be authorized to expend $150.00 for the purchase of reference books. (*Adopted.*)

Moved: That the question of preparing a list of the reference books belonging to the National Research Council be referred to the Research Information Service. (*Adopted.*)

Moved: That the hotel bills connected with attendance on the meetings of April 14–15, 1919, and of April 26–27, 1919, of the members of the Division of Biology and Agriculture be approved, but that this action on the part of the Interim Committee shall not be considered as a precedent. (*Adopted.*)

Moved: That the Interim Committee approve the bills for railroad fare and sleeper for the members of the Executive Committees of the Divisions of Physical Sciences and of Biology and Agriculture for meeting to be held the latter part of May, 1919. (*Adopted.*)

The following recommendations were submitted by Mr. Woods in behalf of the Division of Biology and Agriculture:

That the present Committee on Bibliography of the Division of Biology and Agriculture be continued with the addition of two members to be appointed by the Chair, and that this committee be instructed to coöperate with Mr. Yerkes of the Research Information Service. (*Adopted.*)

That the Fertilizer Committee of the Division of Biology and Agriculture be temporarily continued with Mr. J. B. Lipman as Chairman. (*Adopted.*)

That the Committee on Protein Metabolism in Animal Feeding of the Division of Biology and Agriculture be continued until a new general committee is established. (*Adopted.*)

That the present Committee on Salt Requirements of the Division of Biology and Agriculture be continued, and that Dr. Crocker be substituted for Dr. Woods on this Committee. (*Adopted.*)

The Interim Committee adjourned at 12.15 p.m.

PAUL BROCKETT, *Assistant Secretary.*

MINUTES OF JOINT MEETING OF THE EXECUTIVE BOARD OF THE NATIONAL RESEARCH COUNCIL WITH THE COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES

AT THE NATIONAL RESEARCH COUNCIL BUILDING, MAY 27, 1919, at 9.30 A.M.

Present: Messrs. Bancroft, Carty,* Dunn, Flinn, Howell,* Hussey, Leuschner, Manning, Mathews, Merriam, Millikan, Pearl,* Ransome,* Walcott,* Washburn, Woods, Yerkes.

Mr. Walcott in the Chair during the transaction of the business of the Council of the Academy.

Mr. Merriam in the chair during the transaction of the business of the National Research Council.

The minutes of the regular meetings of the Executive Board of the National Research Council of April 15 and May 13, of the special meeting of the Executive Board of May 8, of the joint meeting of the Executive Board of the National Research Council and the Council of the National Academy of Sciences of April 30, and of the Interim Committee of the National Research Council of May 20, were approved as circulated, with certain amendments which have been included in the minutes of these meetings as previously reported in the PROCEEDINGS. Matters concerning solely the National Academy of Sciences are omitted from these minutes. Report on certain other matters which have not, as yet, been brought to a definite conclusion will be included in the minutes of future meetings.

A report from the Editorial Board of the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES was presented by its chairman, Mr. Raymond Pearl. The following extract concerns the National Research Council:

> A special joint committee of the Editorial Board of the PROCEEDINGS on the one hand, and the National Research Council on the other hand, met and considered the general question of the future relations of the National Research Council and the PROCEEDINGS. The special committee was constituted as follows: For the Editorial Board. the Chairman, the Managing Editor, and Dr. Day; for the National Research Council, Doctors Hale, Merriam, and Yerkes. The general policy worked out by this joint committee was agreed to by the Editorial Board. It was in effect this, that the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES should become in a broader sense than had been true in the past, representative of the activities of the National Research Council, as well as of the National Academy It was understood that the National Research Council should offer to the PROCEEDINGS as official communications of the Research Council of the National Academy of Sciences such material, (intended for publication as bulletins of the Council) as the Council considered to be of permanent scientific value in the PROCEEDINGS. It was felt that in view of the proposed enlargement of the scope of the PROCEEDINGS to represent the activities of the National Research Council that some changes in the typography of the PROCEEDINGS might be desirable and it was agreed that changes looking to the improvement of the PROCEEDINGS in this regard would be inaugurated as soon as agreement on the matter had been reached between the conferees from the two interested bodies.
>
> *Moved:* That the report be referred to the Editorial Board with power. (*Adopted.*)

* Members of the Council of the National Academy of Sciences.

The Council of the Academy adjourned at 10.30 a.m.

The Council of the National Academy of Sciences and the Executive Board of the National Research Council met in joint session at 10.35 a.m.

Mr. Dunn, as Chairman of the Nominating Committee for members at large of the Executive Board, presented a report of progress, stating that four members-at-large of the Executive Board had already been nominated on April 30 and had been appointed by the President of the Academy and that the Committee desired to recommend the appointment of the following additional members-at-large: Messrs. Van H. Manning, Director Bureau of Mines, S. W. Stratton, Director Bureau of Standards, and John J. Carty, Chief Engineer American Telephone and Telegraph Company, 195 Broadway. The Secretary was requested to cast the ballot for the names presented. The Secretary cast the ballot for the nominees and they were declared elected for recommendation for appointment by the President of the National Academy of Sciences to membership in the Council. Mr. Dunn stated that five additional members at large remained to be nominated and that the Committee had in mind to nominate only three of the remaining five in the immediate future.

Moved: That the expenses of Mr. Albert Barrows incident to visiting various state scientific committees and research committees in educational institutions on his way to Washington, be paid from the funds of the Division of Educational Relations, and that Mr. Barrows' salary begin with his services to the Council in this connection. (*Adopted.*)

Moved: That one thousand (1000) copies of the War Organization of the National Research Council pamphlets be printed. (*Adopted.*)

In behalf of the Research Fellowship Board Mr. Leuschner, Acting Secretary of the Board, reported the following appointments to National Research Fellowships for the ensuing year:

E. F. Barker (Physics)
A. E. Caswell (Physics)
F. E. E. Germann (Physics)
Leonard B. Loeb (Physics)
George P. Paine (Physics)
Robert A. Patterson (Physics)
E. Russell Bichowsky (Chemistry)
Emmet K. Carver (Chemistry)
W. D. Rodebush (Chemistry)
Geo. Scatchard (Chemistry)
Warren C. Vosburgh (Chemistry)
Lansing S. Wells (Chemistry)

Mr. J. C. Merriam, Chairman, made the following announcement:

That he had continued the original Committee on Nominations of officers and members of the Executive Board, Messrs. Hale, Millikan, and Noyes, for the nomination of three vice chairmen and that this committee had made the following nominations:

First Vice Chairman—Mr. C. D. Walcott
Second Vice Chairman—Mr. Gano Dunn
Third Vice Chairman—Mr. R. A. Millikan

Moved: That the Secretary cast the ballot for Messrs, C. D. Walcott, Gano Dunn, and R. A. Millikan for First, Second and Third Vice Chairmen respectively, of the National Research Council. (*Adopted.*)

The Secretary reported that he had cast the ballot in accordance with the foregoing resolution and Messrs. Walcott, Dunn, and Millikan were declared First, Second, and Third Vice Chairmen respectively.

The Chairman reported the receipt of a communication from Secretary Redfield stating that he would be pleased to have the National Research Council represented at the World Cotton Conference to be held at Atlantic City, May 28.

Moved: That Mr. Johnston and Mr. H. E. Howe be appointed delegates to represent the National Research Council at the World Cotton Conference to be held at Atlantic City, May 28, and that this appointment carry with it reimbursement from the funds for the general maintenance of the Executive Board for expenses of travel and subsistence. (*Adopted.*)

With reference to the proposed establishment of a popular journal of science it was

Moved: To pass the following resolution, only members of the Council of National Academy of Sciences voting:

WHEREAS, at the meeting of the National Academy of Sciences on April 30 the following motion was adopted:

"That the Council of the National Academy of Sciences be authorized to proceed with arrangements for a popular journal of science, provided arrangements be made for properly financing the journal, and for safeguarding the scientific quality of its contents,"

Resolved by the Council of the National Academy of Sciences that the Executive Board of the National Research Council be requested to assist the Council of the National Academy of Sciences by investigating and reporting back on the feasibility of a popular journal of science, and by securing pledges of funds. (*Adopted.*)

Moved: That Mr. Vernon Kellogg be invited to prepare as promptly as possible for the National Research Council a report on the feasibility of establishing a popular journal of science, on a plan for the organization and direction of such a journal, and on estimates of necessary expenditures in connection therewith. (*Adopted.*)

Mr. Washburn reported that in accordance with the resolution passed by the Executive Board on May 8, 1919, an informal conference concerning the continuation of the Committee on Explosives Investigations, had been held with representatives of the Army, the Navy, and the Bureau of Mines. Present at the Conference were Col. C. Harris, Jr., of the Ordnance Department of the Army, Lieut. Commdr. T. S. Wilkinson of the Bureau of Ordnance of the Navy, Dr. C. E. Munroe, Chairman of the Committee on Explosives Investigations, and the Acting Chairman of the Division of Chemistry and Chemical Technology. Mr. Van H. Manning of the Bureau of Mines was unable to be present owing to another engagement, but his views were known to the other members of the conference. Mr. Washburn submitted a recommendation from the conference that letters be addressed to the Bureau of Ordnance of the Navy, to the Ordnance Department of the Army, and to the Bureau of Mines, suggesting that these organizations coöperate in making arrangements for the permanent continuance of the Committee on Explosives Investigations, such coöperation to involve financial support to the extent of $2000 per annum by each of these three organizations.

Moved: That the suggestions contained in the report of Mr. Washburn be approved. (*Adopted.*)

The President of the National Academy of Sciences presented the following report on the proposed lease of the Navy League Building: An offer has been made to the agent of the building of $6500 a year for a two year lease, with the privilege of extending the lease for another year and with the understanding that the building shall be turned over to the National Research Council in thoroughly good order. It is expected that a definite report will be received by June 3.

The Acting Chairman announced that he had appointed an informal committee consisting of Messrs. Walcott, Leuschner, and Yerkes, to report on the representation of the United States at the international meetings to be held at Brussels beginning July 16. This committee reported that nominations were being received from the proper sources, that the traveling expenses of some of the nominees could be provided by educational and research institutions, but that it had become evident that the United States would not be properly represented unless additional provision for traveling expenses could be made; that in particular government bureaus were not allowed, under the law, to provide traveling expenses to these meetings for their members. Under these circumstances the President of the National Academy of Sciences had addressed a letter to the President of the United States, emphasizing the importance of adequate representation at the Brussels meeting on the part of the United States, and recommending that the Government provide the necessary traveling expenses of delegates.

The Committee further recommended that in case traveling expenses should be appropriated as requested, those delegates whose expenses are to be paid from government funds should be distributed approximately as follows:

For the International Research Council and the Unions which are already in process of formation and will be able to begin active work at Brussels, namely the Astronomical, Geophysical, Chemical, and Medical Unions, approximately 5 each.

For the conference to be held in connection with the proposed formation of Unions in Physics, Geology, Biology, Mathematics, and Bibliography 1 to 2 each, with the understanding that this distribution is only tentative. A provision of the International Research Council and of the Scientific Unions operating provisionally is that the number of delegates is not limited, and it seems desirable to the Committee that additional delegates be accredited if necessary, particularly in astronomy, if their traveling expenses can be provided for from private sources.

Moved: That the foregoing action and recommendations of the Committee, Messrs. Walcott, Leuschner, and Yerkes, on Representation of the United States, at the International meetings to be held at Brussels commencing July 16th, be approved and that the Committee be constituted a Committee on Selection of Delegates with power to nominate delegates in accordance with the plan presented. (*Adopted.*)

The Acting Chairman reported that Mr. Albert L. Barrows had accepted the appointment made on April 30 as Secretary for the Divisions of Educational and States Relations.

On recommendation of the Division of Educational Relations, it was

Moved: That Mr. Vernon Kellogg be elected a member-at-large of the Division of Educational Relations, with the recommendation to the President of the National Academy of Sciences that he be appointed a member of the National Research Council and assigned to that Division. (*Adopted.*)

Mr. Yerkes, as Chairman, presented the following nominations of members of the Research Information Service:

Mr. Joseph Stewart, Special Assistant to the Attorney General, Post Office Department, as official representative of the Department.

Dr. Edwin F. Gay, Central Bureau of Planning and Statistics, member at large.

Dr. Raymond Pearl, School of Hygiene and Public Health, Johns Hopkins University, Baltimore, member at large.

Moved: That the nominations of Messrs Joseph Stewart, Dr. Edwin F. Gay, and Dr. Raymond Pearl as members of the Research Information Service be approved, with the recommendation to the President of the National Academy of Sciences that they be appointed members of the National Research Council and assigned to that Division. (*Adopted.*)

In behalf of the Committee appointed on May 13 with power to arrange with the State Department for the continuation of the Foreign Research Information Service, Mr. Yerkes, as Chairman, presented the following report:

In accordance with motion adopted at Executive Board meeting May 13 the Acting Chairman of the Council and the Chairman of the Research Information Service with the assistance of Messrs. Bancroft, Dunn, and Mathews, as members of a committee appointed to take action with reference to the future of the foreign information service, have prepared the following resolutions.

WHEREAS the Research Information Service of the National Research Council, through its scientific attachés in London, Paris, and Rome, has rendered important service to the Departments of War and the Navy and has effectively coöperated with other Departments, notably that of State:

And whereas the importance of this scientific assistance has been recognized and appreciated by the Departments especially concerned and is deemed worthy of continuance;

And whereas the possibility and prospect of closer commercial and social relations between nations renders especially desirable prompt interchange of ideas and results of research to the end that duplication of effort may be avoided, plans coördinated, and the progress of civilization furthered by effective scientific and technical coöperation:

And whereas during the coming months and from time to time thereafter numerous international organizations (some of them based on treaties between nations) will meet in Europe for the consideration of political, social, industrial, and educational problems of the utmost importance with present varied scientific aspects;

Be It Resolved: That in the judgment of the Executive Board of the National Research Council the continuance of the Research Information Service in London, Paris, and Rome, is of vital importance;

That in each of these centers a scientific attaché should be maintained by the United States Government as an official representative of the scientific and technical interests of the Government and of the National Research Council.

On May 23 the Acting Chairman of the Council presented to the Third Assistant Secretary of State the substance of these resolutions with an estimate of the expense of continuing the service of scientific attaches in London and Paris. The Third Assistant Secretary of State advised that a statement of the need for this service for the year beginning July 1, 1919, should be transmitted immediately to the President of the United States.

In accordance with this advice a letter was prepared by your committee and transmitted to the State Department for approval and comment.

Moved: That the offices of the Research Information Service in London, Paris, and Rome be closed June 30, 1919, unless Government funds become available for the continuation of the Foreign Research Information Service. (*Adopted.*)

In behalf of the Division of Physical Sciences, Mr. Millikan as retiring Chairman, recommended that a communication be sent to the Rockefeller Foundation requesting an annual appropriation of $20,000 for two or three years for traveling expenses in connection with the plan of stimulating and organizing research in physical subjects through the formation of groups of research men in these subjects.

Moved: That the Executive Board approve the foregoing recommendations of the Division of Physical Sciences and that the Chairman of the Council be authorized to address a letter to the Rockefeller Foundation requesting an annual appropriation of $20,000 for two or three years in support of these plans. (*Adopted.*)

Moved: That the following recommendations from the Division of Biology and Agriculture be approved: It is the sense of the Division of Biology and Agriculture that it is desirable to ask support for a number of National Research Fellowships in the Division of Biology and Agriculture, comparable in general type to those offered in physics and chemistry. (*Adopted.*)

Moved: That the Division of Geology and Geography be authorized to pay from the General Maintenance allotment of the Division the expenses of railroad fare and Pullman for the members attending a meeting of the Division to be held June 5 and 6 1919. *Adopted.*

Moved: That the following Committee on Paleobotany of the Division of Geology and Geography be approved:

David White (Chairman), U. S. Geological Survey
R. S. Bassler, U. S. National Museum
E. W. Berry, Johns Hopkins University
J. M. Clarke, State Geologist of New York
F. H. Knowlton, U. S. Geological Survey
J. C. Merriam, University of California. (*Adopted.*)

Mr. Leuschner, the Acting Chairman of the Division of Physical Sciences presented a recommendation from the Provisional Executive Committee of the American Section of the proposed International Geophysical Union to the effect that the railroad fare and Pullman expenses of the members of the Section attending the organizing meeting of the Section to be held on June 24 and 25, 1919, be met from the General Maintenance fund of the Executive Board allotment.

Moved: That the railroad and Pullman expense of members attending the organizing meeting on June 24 and 25, 1919, of the American Section of the proposed International Geophysical Union, not to exceed $100 in the case of any member, be approved, such expenses to be met from the General Maintenance fund of the Executive Board allotment. (*Adopted.*)

In behalf of the Division of Chemistry and Chemical Technology Mr. Washburn, as Acting Chairman, submitted the following recommendations:

That the membership of the committee on Synthetic Drugs be constituted as follows:

Moses Gomberg, Ph.D., Prof. of Organic Chemistry, Univ. of Michigan, Ann Arbor, Mich.

G. W. McCoy, M.D., Director of the Hygiene Laboratory, U. S. Pubic Health Service, Washington, D. C.

Francis M. Phelps, Lawyer, Pacific Building, Washington, D. C.

W. A. Puckner, Phar.D., Director of Chemical Laboratory of the American Medical Association and Sec'y of the Council of Pharmacy and Chemistry of the American Medical Association.

Edw. S. Rogers, Attorney, Peoples Gas Bldg., Chicago, Ill.

Julius Stieglitz, Ph.D., Sc.D., Chem.D., Prof. of Chemistry, University of Chicago, Chicago, Ill. *(Approved.)*

That the Executive Board approve the preparation of monographs in accordance with the plan outlined in Section 3, of the report of the Committee on Publication of Compendia of Chemical Literature (see minutes of the Executive Board of April 30), and that it accept the invitation contained in the report to appoint one member of a Board of Trustees which shall have power to organize and control the undertaking. *(Approved.)*

Moved: That the following plan of organization of the Division of Anthropology and Psychology, together with the recommendations presented, be approved:

Organization of the Division of Anthropology and Psychology

It is recommended that the Division of Anthropology and Psychology of the National Research Council be organized as follows:

(1) The membership of the Division shall be equally divided between psychology and anthropology, and for the present shall be limited to nine members representing psychology and nine representing anthropology.

(2) The leading organization in each of the two subjects represented shall be asked to nominate six representatives for membership in the Division, the six persons thus nominated, in conference with the Executive Board of the Research Council to nominate the remaining three for each subject. It is understood that the American Psychological Association will nominate the six members for psychology, and the American Anthropological Association the six members for anthropology.

(3) The eighteen members selected shall elect from this number a Chairman for the Division of Anthropology and Psychology, and the nine representatives of each subject shall elect a chairman for a section, to be organized for each subject.

(4) For the present the work of the Division shall be divided so that general matters will be cared for by the whole Division under the direction of the Chairman of the Division, the sections holding rather frequent meetings under the direction of the Section Chairman.

(5) The executive business of the Division including general matters for the Division as a whole and those covering the work of the two sections shall be handled by a Secretary at a salary of $3000 per year, the Secretary to be resident in Washington. In view of this organization it seems desirable that the sum of $3000 being the difference between the salary of the Secretary and the normal salary of the head of a division be made available for expenses of the Chairman of the Division and the Chairmen of the two Sections, in connection with journeys to Washington with such residence at headquarters as may be necessary in conducting the work of the Division. *(Adopted.)*

The meeting adjourned at 1.05 p.m.

PAUL BROCKETT, *Assistant Secretary.*

MINUTES OF THE MEETING OF THE INTERIM COMMITTEE

AT THE NATIONAL RESEARCH COUNCIL BUILDING, JUNE 3, 1919, AT 9.30 A.M.

Present: Messrs. Angell, Bancroft, Clevenger, Leuschner, Mathews, Merriam, Washburn, Yerkes and, by invitation, H. E. Howe.

Mr. Merriam in the chair.

The Secretary reported that in view of the fact that the Government disbursing office in London, through which disbursements were made to the Foreign Research Information Service at London and Paris, had probably been closed on June 1, it would be necessary to advance a sufficient sum of money from the funds appropriated to the Executive Board for the continuance of the offices of the Scientific Attachés in London and Paris during the month of June and for the traveling expenses incident to the return to the United States of the staffs of these offices.

Moved: That, owing to the closing of the disbursing office in London, an advance be made from the funds of the National Research Council, allotted to the Executive Board, unless other means can be found, to cover the emergency in the disbursement of government funds for the offices of the Scientific Attachés in London and Paris during the month of June, with the understanding that the sum so advanced will be returned to the National Research Council from the President's allotment for the expenses of the Council through the Council of National Defense; that the amount to be advanced be left to the discretion of the Chairman and Secretary, provided it shall not exceed $6000 in all; $3000 for the London and $3000 for the Paris office. *(Adopted.)*

Moved: That the expenses of Scientific Attachés Mendenhall, Howe, and Washington as delegates of the National Research Council to the meetings in Brussels be referred to the Committee on Delegates (Messrs. Walcott, Leuschner, Yerkes) with power, with the understanding that the total expenses involved will not exceed $1500. *(Adopted.)*

The Chairman reported on the repairs and alterations required to prepare the Navy League Building for the use of the Council and stated that the owners had asked for a week's delay in completing the lease on account of a prospective sale of the property, and that under these circumstances an option to June 15, 1919 on the removal of the lease of the present quarters had been secured.

The Chairman reported that in accordance with the resolution passed by the Executive Board on May 27, Mr. Gellert Alleman, Swarthmore College, Swarthmore, Pa., had been appointed a member of the Board of Trustees which shall have power to organize and control the undertaking in regard to the preparation of monographs proposed in the report of the Committee on Publication of Compendia of Chemical Literature, etc. (see minutes of meeting of Executive Board of April 30).

The Chairman recommended that the record be completed by reporting the appointment of Mr. John Johnston, Chairman of the Section on Industrial Relations under the old organization, as Acting Chairman, without salary, of the Division of Industrial Relations under the new organization, to date from April 15, 1919. *(Approved.)*

The Chairman announced the membership of the joint Committee on the Publication of Critical Tables of Physical and Chemical Constants, authorized on April 15, to be as follows:

Messrs. Bumstead and Millikan, Division of Physical Sciences.
Messrs. Bancroft and Washburn, Division of Chemistry and Chemical Technology.
Mr. S. W. Stratton, Bureau of Standards.
Mr. F. E. Fowle, Smithsonian Institution.

The Acting Chairman of the Division of Chemistry and Chemical Technology presented a report of the joint Committee on the Publication of Critical Tables of Physical and Chemical Constants, which was adopted in the following amended form:

Your committee appointed to consider the plans proposed by the American Chemical Society with reference to the preparation of Critical Tables of Physical and Chemical Constants, submits the following report:

(1) It is recommended that the Council approve of preparing critical volumes of physical and chemical constants and related numerical data, as described in that report, but with the changes indicated by the italicized portions of the following extract from the report: Section II, 3 (confer minutes of meeting of April 22).

(1) The work *shall* not be a mere compilation, but *shall* represent a critical digest of physico-chemical constants.

(2) The compilation *shall* be published in separate parts. This *will* greatly facilitate the editing, greatly accelerate the publication of certain most important parts, and greatly facilitate the problem of keeping the work up-to-date without incurring the necessity of reprinting a large volume.

(3) The business control of the publication *shall* be placed in the hands of three Trustees of whom one (the Chairman) *shall* be nominated by the *Chairman* of the National Research Council and one each by the President of the American Chemical Society and the President of the American Physical Society. They shall hold office for one year and be eligible for re-election. *They shall have the power to add to their number, subject to the approval of the National Research Council.* The Trustees shall have the power to interest scientific bodies (such as the National Research Council, the Smithsonian Institution, Government Bureaus, etc.) or some publishing house in the preparation and publication either of the whole compilation (subject to the scientific control discussed below) or of individual parts of the compilation, or to recommend any plan of financing the undertaking that they may deem wise. The undertaking is to be considered primarily in charge of the National Research

Council with the support of the American Chemical Society, the American Physical Society and other scientific societies.

(4) The scientific control of the preparation of the volume on physico-chemical constants shall be vested in a committee of seven to be appointed by the Chairman of the National Research Council: three members on nomination by the Division of Chemistry and Chemical Technology and three members on nomination by the Division of Physical Sciences. The Chairman of the Committee will be the paid Editor-in-Chief of the work and will be selected by the *Chairman* of the National Research Council, the President of the American Chemical Society and the President of the American Physical Society. (Interested Scientific Societies including Electrochemical Society, the Institute of Chemical Engineers, etc., are represented in the Divisions of Chemistry and Chemical Technology and Physical Sciences of the National Research Council.) The members of the Committee are to be appointed for one year *or for such other term as the appointing power may see fit* and are to be eligible for reappointment.

(5) International coöperation is desired in carrying out this project and the International Chemical Union shall be requested to make suggestions as to such international representation on the Board of Scientific Control as it deems desirable.

Moved: That the delegates to the meetings of the International Chemical Union to be held in July at London and Brussels be authorized to present the foregoing report as the American plan for the preparation of critical tables of physical and chemical constants.

(*Adopted.*)

The Secretary reported that the Research Information Service had offered to abstract and index the minutes of the meetings of the Executive Board and of the Divisions.

Moved: That the Interim Committee approve the offer of the Research Information Service to abstract and index the minutes of the Executive Board and of the Divisions, and that the details involved in this plan be left to the Secretary of the Council and the Chairman of the Research Information Service. (*Adopted.*)

Moved: That the Chairmen of Divisions be requested to invite the Vice-chairmen of their Divisions to attend meetings of the Interim Committee whenever they are present in Washington. (*Adopted.*)

Mr. Yerkes, Chairman of the Research Information Service, presented the following report:

At a meeting held in the offices of the Research Council Thursday, May 29, the division was organized with Robert M. Yerkes as Chairman and Rear Admiral Albert P. Niblack, as Vice-chairman. An executive committee consisting of five members was elected. The membership consists of the Chairman and Vice-chairman of the Division, Wesley C. Frost representng the government, C. E. Mendenhall representing the divisions of Science and Technology (Colonel W. D. Bancroft was elected to act during the absence of Mr. Mendenhall) and Edwin F. Gay from the membership at large.

The division took the following action relative to activities proposed for consideration:

(a) *Personnel Bureau.* That the matter of establishing a personnel bureau to undertake the preparation of a catalog of men and women qualified for research in science and technology. be referred to the executive committee of the Division with instructions to report back to the Division.

That it be recommended to the Executive Board that the following projects be undertaken:

(b) *Catalog of Current Investigations.* That the preparation of a catalog of current scientific and technological investigations be undertaken by the division.

(c) *Abstracts and Handbooks.* That the division further the preparation of such aids to research as systematic bibliographies, abstracts, digests and handbooks.

(d) *Publications.* That the editing and management of the proposed bulletins of the Research Council be placed under the Research Information Service.

(e) *Centralization of Scientific Periodicals.* That a plan for coöperation in the publication of scientific materials be formulated.

(f) *Catalog of Research Information.* That a general catalog of research information be acquired and maintained by the Division.

Moved: That the Interim Committee approve the organization of the Research Information Service, as outlined and the action taken relative to proposed activities of the Service. (*Adopted.*)

On recommendation of Mr. Leuschner the Acting Chairman of the Division of Physical Sciences, it was

Moved: That chairmen of committees of the American Section of the proposed International Astronomical Union attending the meeting of the Section to be held in Washington on June 23 and 24 for the purpose of discussing reports and instructing delegates, be reimbursed for railroad fare and Pullman expenses with a limit of $100 in each case and a total limit of $250. (*Adopted.*)

The Chairman of the Research Information Service presented suggestions concerning the issuance of publications on the part of the National Research Council, especially of a series of special bulletins.

Moved: That the report on issuing publications be transmitted to the members of the Executive Board and that the report be made a special order for the meeting of the Executive Board to be held on Tuesday, June 10. (*Adopted.*)

On recommendation of Mr. Yerkes it was

Moved: That an additional sum of $300 be allotted to the Committee on Psychology from the unappropriated funds of the Council for special study of data regarding men recommended for discharge or for neuro-psychiatric examination. (*Adopted.*)

On Recommendation of the Chairman of the Research Information Service it was

Moved: To reimburse members of the Research Information Service attending the organizing meeting on May 29 for traveling expenses and to provide for their entertainment at luncheon, with the understanding that the total cost be in the neighborhood of $50, the amount to be charged to the funds appropriated to the Executive Board. (*Adopted.*)

The Interim Committee adjourned at 12.50 p.m.

PAUL BROCKETT, *Assistant Secretary.*

MINUTES OF THE MEETING OF THE EXECUTIVE BOARD

AT THE NATIONAL RESEARCH COUNCIL BUILDING, JUNE 10, 1919, AT 9.30 A.M.

Present: Messrs. Bancroft, Flinn, Hussey, Leuschner, McClung, Merriam, Ransome, Stratton, Washburn, Yerkes, and, by invitation, H. E. Howe.

Mr. Merriam, Chairman of the Council in the Chair.

The minutes of the joint meeting of the Executive Board of the National Research Council with the Council of the National Academy of Sciences of May 27 and of the meeting of the Interim Committee of June 3 were approved as printed, with certain amendments, which have been included in the minutes as printed in the PROCEEDINGS.

The Secretary, Mr. Leuschner, reported the following membership of the Pulverizing Committee, which was approved at the meeting of the Interim Committee held on June 3, but which was not transmitted to him by the Division of Engineering in time to be included in the minutes of that meeting:

Committee on Pulverizing, Division of Engineering

Mr. G. H. Clevenger, Chairman, Engineering Division, National Research Council, New York City.
Mr. Paul Avery, Esperanza Mining Company, El Ore, Mexico.
Mr. C. H. Benedict, Calumet and Hecla Mining Company, Lake Linden, Michigan.
Mr. A. L. Bloomfield, Golden Cycle Mining and Milling Company, Colorado Springs, Colorado.
Mr. D. S. Calland, Cia. Real del Monte Pachuca, Pachuca, Hidalgo, Mexico.
Mr. Allan J. Clark, Homestake Mining Company, Lead, South Dakota.
Prof. E. W. Davis, Supt. Mines Experiment Station School of Mines, University of Minnesota, Minneapolis, Minnesota.
Mr. J. V. N. Dorr, The Door Company, New York.
Mr. H. W. Fox, Westport, Connecticut.
Mr. Frank Janney, Utah Copper Company, Garfield, Utah.
Mr. A. H. Jones, Tonopah-Belmont Development Company, Tonopah, Nevada.
Mr. B. F. Morrow, Anaconda Copper Mining Company, Butte, Montana.
Mr. Luther C. Lennox, Colorado Springs, Colorado.
Mr. W. M. Rossberg, Timber-Butte Mining Company, Butte, Montana.
Mr. W. G. Swart, 808 Sellwood Building, Duluth, Minnesota.
Mr. R. B. Yerxa, Miami Copper Company, Miami, Arizona.
Mr. Louis D. Mills, San Francisco, California.

On recommendation of the Secretary it was

Moved: That the members of the Division of Medical Sciences attending the organizing meeting of the Division on Monday, June 9, be reimbursed for railroad and Pullman fare from the General Maintenance fund of the Executive Board. (*Adopted.*)

Moved: That the members of the Division of Industrial Relations attending the organizing meeting of the Division on Wednesday, June 11, be reimbursed for railroad and Pullman fare from General Maintenance funds of the Division. (*Adopted.*)

Moved: That Mr. E. W. Washburn be added to the Committee on Organization of Administration. (*Adopted.*)

The Chairman stated that Mr. Clevenger has been invited by the American Society of Mechanical Engineers to represent the National Research Council and present a paper at its Detroit meeting June 17.

Moved: That the expenses of Mr. Clevenger incident to his attendance on the meeting of the American Society of Mechanical Engineers at Detroit be paid from the General Maintenance fund of the Division of Engineering. (*Adopted.*)

Moved: That the dues of $100 of the National Research Council to the American Council on Education for the current year be paid from the General Maintenance Fund of the Executive Board. (*Adopted.*)

Moved: That the salary of Mr. H. E. Howe of the Division of Industrial Relations begin May, 1, 1919. (*Adopted.*)

Moved: That in accordance with the recommendation of the Bureau of Ordnance, Lieutenant-Commander O. M. Hustvedt represent the Bureau of Ordnance of the Navy on the Committee on Explosives Investigations in place of Lieutenant-Commander T. S. Wilkinson. (*Adopted.*)

The Chairman reported that Messrs. John Johnston and H. E. Howe had represented the National Research Council at the meeting of The World Cotton Conference at Atlantic City, N. J., May 28, 1919.

The Chairman reported that it was necessary to finance the work of the Intelligence Scales Committee, consisting of Messrs. Haggerty, Terman, Thorndike, Whipple, and Yerkes, Chairman, from the appropriation of $25,000 from the General Education Board.

Moved: That the experts in psychology employed by the Intelligence Scales Committee be paid at the rate of $5 an hour. (*Adopted.*)

Mr. Yerkes, Chairman of the Research Information Service, presented a report on publications which was adopted in the following form:

A joint committee of the National Academy of Sciences and of the National Research Council has agreed that material of permanent scientific value offered to the Research Council for publication shall be placed in the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES and reprinted for distribution by the Research Council. All other material of the Research Council presumably would be published directly or reprinted as seemed desirable from other periodicals.

The arrangement recommended by this joint committee renders it highly desirable that the form of publication adopted by the Research Council be the same as that of the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

There are obvious reasons why the Research Council should seriously consider the publication of propaganda as contrasted with other types of scientific material, but it is not clear that re-publication of material of scientific value is desirable.

For consideration by the Executive Board of the National Research Council the following proposals are submitted:

(1) That a publication to be known as the *Bulletin of the National Research Council* be established.

(2) That this series shall include the proceedings of the National Research Council and its divisions, publicity and propaganda material, reports of committees, and other special reports.

(3) That the *Bulletin* shall appear irregularly and that within reasonable limits it may vary in form in accordance with the requirements of the material.

(4) That the several bulletins shall be numbered consecutively and shall be so arranged that approximately 500 pages shall constitute a volume.

(5) That the regular subscription price shall be fixed at $5.00 per volume.

(6) That the bulletins shall be sold separately, except in case of strictly publicity material, at a minimum price of ten cents for numbers of not more than ten pages, and at the rate of one-half cent for each page in excess of ten.

(7) That the size of type page be 27 by 45 picas, as in the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, and the type number 31 monotype, 11 point, with 2 point leads.

(8) That a distinctive cover be selected for the *Bulletin*, which shall bear on its title page the name "Bulletin of the National Research Council" the volume number, bulletin number, serial number, title and author of the paper, and the date and place of publication.

Moved: That the following bulletins be published by the Council in the manner and edition indicated, and that the Committee be given power to determine the issue of the regular series of full sets and increase the number of copies up to 50%, according to demand.

1. The National Importance of Scientific and Industrial Research by Hale and others, to be printed as *number one* of the *Bulletin of the National Research Council* in an edition of *two thousand copies.*

2. Report of the Patent Committee of the National Research Council, to be printed as *number two* of the *Bulletin* in an edition of *two thousand copies.*

3. Report of the Psychology Committee of the National Research Council, to be published as *number three* of the *Bulletin* in an edition of *two thousand copies.*

4. Some Problems of Sidereal Astronomy by Henry Norris Russell, to be published in the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES and reprinted as *number four* of the *Bulletin* in an edition of *one thousand copies.*

5. Refractory Materials as a Field for Research by Edward W. Washburn, to be printed as *number five* of the *Bulletin* in an edition of *one thousand copies.*

6. Industrial Research by F. B. Jewett, to be printed as *number six* of the *Bulletin* in an edition of *two thousand copies.* (*Adopted.*)

Moved: That all material prepared under the auspices of the National Research Council and printed in other places than the *Bulletin* be collected in the form of reprints and included in a numbered series of papers to be issued by the National Research Council under such title as the Committee on Publication may decide. (*Adopted.*)

The Secretary called attention to the resolution passed some time ago that all manuscripts for publication should be submitted to the Publication Committee of the National Research Council before being published in any journal.

The Secretary presented a report of the Committee on Administration of Organization on bonus to employes as additional pay to salaries for the past year, providing for an allotment of $1320 from the unappropriated funds of the Council.

Moved: That the report of the Committee on Administration of Organization providing a bonus for certain employees be approved and that the sum of $1320 be appropriated for the purpose from the unallotted funds of the National Research Council. (*Adopted.*)

The report of the Treasurer for the month of May was received and placed on file.

On recommendation of Mr. Washburn, Acting Chairman of the Division of Chemistry and Chemical Technology, it was

Moved: That the report by the Committee on Publication of Compendia of Chemical Literature, etc., to the President and Council of the American Chemical Society, and the recommendations of the Division of Chemistry and Chemical Technology with respect to the Formation of an International Chemical Council be printed in an edition of 100 copies, for use at the meetings in London and that the expenses of the printing be paid from the Maintenance fund of the Division of Chemistry and Chemical Technology. (*Adopted.*)

The Acting Chairman of the Division of Geology and Geography presented the following report:

At a meeting of the Division held on June 5 and 6, the following temporary committees were appointed.

Funds: Ralph Arnold, Chairman.
Rocky Mountain and Geology Conference: Eliot Blackwelder, Chairman.
Committee on Certain Seismological Investigations: H. F. Reid, Chairman.
Conference Committee on Survey of the Sea: J. Russell Smith, Chairman.
List of Scientific Travelers: Isaiah Bowman, Chairman.
Development of Geographical Sciences: W. M. Davis, Chairman.

The Division passed the following resolution on the coördination in field methods of map-making agencies of the Government which it has referred to the Division of Government Relations.

WHEREAS the several mapping agencies of the United States are making actual surveys by different methods on different scales and with wide variation in accuracy of field work.

WHEREAS the results of actual field surveys are not mutually available to the different map-making organizations because of these differences and a lack of means by which the relative accuracy of the different parts of the field work can be readily ascertained.

WHEREAS such lack of coördination in field methods and degree of accuracy leads to surveys and avoidable expense, the Division of Geology and Geography.

Recommends to the Division of Government Relations that a Committee be appointed representing the several map-making agencies of the Government to arrange a plan of operation by which organizations conducting surveys secure and record their field data in such manner that they may be fully usable by other map-making agencies of the Government interested in the same areas.

To this end their Committee should define

1. The degree of accuracy or "tolerance" in field work.
2. Standard methods of expression which shall discriminate the relative accuracy of determination of the several horizontal and vertical elements.
3. One or more standard scales and projections for field mapping.

It is further suggested that this work may be done by a new committee or entrusted to the recently organized Committee of Aeronautic Mapping if its scope may be broadened.

The Division requests the appointment of a Conference Committee by the Division of Biology on Survey of the Sea, also the appointment of a member of the Division of Physical Sciences on its Committee on certain proposals for seismological investigations offered by Dr. Wood.

The Division requests the National Research Council to prepare for publication a record of the work of scientific men in connection with the war.

In response to the inquiry from the Secretary of the National Research Council, the Division

Voted that the Division of Geology and Geography approve the formation of international associations of geologists and of geographers under the auspices of the International Research Council and recommend that two delegates—a geologist and a geographer—be sent to the conference to be held in Brussels, in July 1919.

It also passed the following resolutions:

That this Division recognizing the high value of the scientific work of "The Inquiry" (preparatory to The Peace Congress) recommends to the Executive Board of the National Research Council the appointment of a committee of the Council to confer at an appropriate time with the Department of State with reference to the publication of the scientific results of "The Inquiry."

Moved: That the request of the Division of Geology and Geography that the National Research Council prepare for publication a record of the work of scientific men in connection with the war be referred to the Research Information Service for investigation and report. (*Adopted.*)

Moved: That the formation of international associations of geologists and geographers under the auspices of the International Research Council and the recommendation that two delegates, a geologist and a geographer, be sent to the conference to be held in Brussels in July be approved. (*Adopted.*)

Moved: That the recommendation of the Division of Geology and Geography that a Committee of the Council be appointed to confer at an appropriate time with the Department of State with reference to the publication of the scientific results of "The Inquiry" (preparatory to The Peace Congress) be approved. (*Adopted.*)

Mr. Hussey, Acting Chairman of the Division of Medical Sciences, presented the following report:

The organization meeting of the Division of Medical Sciences was held in Philadelphia, June 9, 1919. All elected members except five were present. There are three Society nominations which remain to be made, namely those of The American Association of Anatomists, The American Society of Biological Chemists, and the American Neurological Society. Doctors W. W. Keen and F. S. Lee were present by special invitation.

The following officers were elected: Dr. H. A. Christian, Chairman; Dr. R. G. Hussey, Vice Chairman; Dr. Hussey to serve as Acting Chairman until Dr. Christian can make arrangements to take office.

The following members were elected to serve on the Executive Committee: Doctors Simon Flexner, Reid Hunt, W. H. Howell, R. M. Pearce and Colonel F. F. Russell.

The terms of office for the members determined by lot at the meeting, are as follows:

One year term	*2 year term*	*3 year term*
George W. Crile	G. C. Huber	H. A. Christian
E. R. Stitt	W. S. Thayer	Wm. H. Welch
Victor C. Vaughan	T. B. Hartzell	Simon Flexner
A. W. Crane	Reid Hunt	Peyton Rous
H. Gideon Wells	F. P. Gay	Howard T. Karsner
David L. Edsall	Joseph Erlanger	Richard N. Pearce
W. H. Howell	Anatomical Society	F. F. Russell
Neurological Society	American Society of Biological Chemists.	

Consideration was given to a communication from the Secretary regarding the International Research Council. The following action was taken

regarding medical interests and representation in international scientific organization: that this Division go on record as being in accord with the sentiments of the resolutions passed at the London meeting regarding scientific relations with men of the Central Powers:

That this Division go on record as stating without qualifications, their approval of the admittance of Neutral Countries to any international organization that may be formed;

That this Division will serve as the American Section of any International Medical Organization proposed. Five delegates were nominated to attend the Brussels meeting.

A committee was appointed to take charge of questions regarding international organization, this committee to be known as the Committee on International Coöperation in Medical Sciences and to be constituted as follows: Doctors Christian, Flexner, Keen (Chairman), Lee, Welch, Colonel Russell and the Acting Chairman of the Division (ex officio); together with the delegates. A meeting of this Committee has been called to be held at Atlantic City, Wednesday, June 11.

The Division meeting adjourned until some date in late September or early October subject to the call of the Chairman.

Immediately following the meeting the Executive Committee met in a short session. It was voted that all existing committees be continued as constituted in the War Organization subject to later action by the Executive Committee.

On recommendation of Mr. McClung, Chairman of the Division of Biology and Agriculture, it was

Moved: That an additional sum of $500 be appropriated to the General Maintenance fund of the Division of Biology and Agriculture to meet the traveling expenses of members of the Executive Committee in attendance on the meeting held May 31–June 1—and on meeting to be held during the summer, and to provide for incidental expenses of the Division. (*Adopted.*)

Moved: That the unexpended sum of $1000 allotted to the Division of Biology and Agriculture for the rodent pest investigation revert to the general fund. (*Adopted.*)

Moved: That the sum of $1000 be appropriated for the use of the Committee on Plant Pathology of the Division of Biology and Agriculture to complete its work for the year, this amount to be used in payment of railroad and Pullman fares of committee members to conferences. (*Adopted.*)

Moved: That the following Committee on Food and Nutrition of the Division of Biology and Agriculture be approved:

J. R. Murlin, Chairman
H. P. Armsby
E. B. Forbes
C. F. Langworthy
Graham Lusk
E. V. McCollum
H. C. Sherman
A. E. Taylor
A. F. Woods

(*Adopted.*)

The Chairman announced the following initial organization of the Committee on Pacific Exploration:

Wm. Morris Davis, Harvard University, Cambridge, Mass.
Herbert E. Gregory, Yale University, New Haven, Conn.

W. E. Ritter, Scripps Institute, La Jolla, Calif.
G. F. MacEwen, Scripps Institute, La Jolla, Calif.
R. A. Daly, Harvard University, Cambridge, Mass.
Alfred G. Mayor, Director, Department Marine Biology, Carnegie Institution, Washington, D. C. (*Approved.*)

Mr. Mathews, Acting Chairman of the Division of Geology and Geography

Moved: That Mr. J. C. Merriam be asked to serve as a member and Chairman of the Committee on Pacific Exploration. (*Adopted.*)

The Executive Board adjourned at 1.00 p.m.

PAUL BROCKETT, *Assistant Secretary.*

MINUTES OF THE MEETING OF THE INTERIM COMMITTEE

AT THE NATIONAL RESEARCH COUNCIL BUILDING, JUNE 17, 1919, AT 9.30 A.M.

Present: Messrs. Leuschner, McClung, Merriam, and Washburn.
Mr. Merriam, Chairman of the Council, in the Chair.

Moved: That an allotment of $250 be made from unappropriated government funds for the expense of the Washington branch of the Research Information Service to cover salaries and incidental expenses to June 30, 1919. (*Adopted.*)

Moved: That the Division of Engineering be authorized to apply a sum of about $50 from its maintenance fund in reimbursing members of the Committee on Investigation of Neumann Bands attending a meeting to be held in the near future, for railway and Pullman expenses. (*Adopted.*)

Moved: That a petty cash allowance of $100 be set aside from its general maintenance fund for the New York office of the Division of Engineering for June, 1919, and thereafter a monthly petty cash allowance of $30 including the balance from the previous month, with the provision that a detailed statement of expenditure be submitted to the Treasurer of the Council at the end of each month. (*Adopted.*)

The Committee on the Apportionment of Space in the Navy League Building consisting of Messrs. Mathews (Chairman), Leuschner, and Yerkes, presented a report on the assignment of rooms, repairs, and alterations, and made the following recommendation: That, on the assumption that the furniture bought from government funds will be available for the use of the Council after June 30, an offer be made to the Navy League for the purchase of the following equipment at the prices stated:

Awnings	$150.00
Fifteen metal filing cabinets $30 each	450.00
Furnishings in Women's Rest Room	40.00
Coal	75.00
Shelving	40.00
Two double pedestal typewriting desks $25 each	50.00
	$805.00

Moved: That the Committee on the Apportionment of Space in the Navy League Building confer with the chairmen of the Divisions as to the proposed assignment of space and report at the meeting of the Executive Board to be held on June 24, 1919. (*Adopted.*)

Moved: That the offer recommended by the Committee on the Apportionment of Space in the Navy League Building for the purchase of furniture and fixtures specified above be approved. (*Adopted.*)

Moved: That authority be given to the Chief Clerk to move the offices of the National Research Council from 1023 16th Street to the Navy League Building at 1201 16th Street, and that the expenses of moving be paid from government funds. (*Adopted.*)

Moved: That the Chief Clerk, be authorized to buy the paper and order the printing of the necessary letterheads for the use of the Council, using his discretion, with the approval of the Secretary, as to the use of government funds in this expenditure. (*Adopted.*)

The Secretary, Mr. Leuschner, rendered a report on the existing committees of the Executive Board.

Moved: That the following committees be discharged:

Reorganization of Council, authorized and appointed November 12, 1918, Messrs. Merriam (Chairman), H. M. Howe, Millikan, Pupin, Johnston; reorganized Dec. 31, 1918, with Mr. Noyes in place of Mr. Merriam and with Mr. Hale as Chairman.

Preparation and Publication of History of Research Activities in Science in this country during the war, authorized and appointed November 20, 1918, Messrs, Yerkes, (Chairman), Teggert, Gilbert.

Smith-Howard Bill, authorized and appointed December 4, 1918, Messrs. Leuschner, (Chairman), H. M. Howe, Johnston, Pupin.

Proposed Chicago Meeting with Research Representatives of Middle West Institutions, authorized and appointed December 31, 1918, Messrs. Hale (ex-officio), Chairman, Leuschner, Merriam, Noyes.

To prepare Revised Scheme for the Promotion of Research in Physics and Chemistry, authorized and appointed January 14, 1919, Messrs. Noyes (Chairman), Flexner, Johnston, Millikan, Nichols.

Organization of Division of Engineering, authorized and appointed January 21, 1919, Chairman of the Council, Messrs. Dunn and Howe.

Program of the National Research Council for Annual Meeting of the National Academy of Sciences, appointed April 4, 1919, confirmed April 8, 1919, Messrs. Leuschner (Chairman), Cross, H. M. Howe, Yerkes.

Organization of Government Division, appointed April 4, 1919, confirmed April 8, 1919, Messrs. Yerkes (Chairman), Bancroft, Nichols.

Organization of Division of Industrial Relations, appointed April 4, 1919, confirmed April 8, 1919, Messrs. H. M. Howe (Chairman), Bancroft, Clevenger, Nichols.

Nominations of Officers and Members-at-Large of Executive Board, authorized and appointed April 15, 1919, Messrs. Hale (Chairman), Noyes, Millikan. Discharged April 30, 1919. Reappointment reported May 27, 1919, for nomination of three Vice-chairmen.

Organization of Research Information Service, authorized and appointed May 13, 1919, Messrs. Yerkes (Chairman), Bancroft, Dunn, Merriam, Mathews. (*Adopted.*)

Moved: That the following special and standing committees be continued:

Reconstruction Problems, authorized August 13, 1918, and appointed August 20, 1918, Messrs. Vernon Kellogg (Chairman), F. H. Newell (Vice-chairman), Raphael Zon, Walton H. Hamilton.

Organization of Administration, authorized and appointed April 1, 1919, Messrs. Cross (Chairman), Clevenger, Hussey, Leuschner, Yerkes; reorganized April 22, 1919, with Secretary Leuschner as Chairman ex-officio. Mr. Washburn added June 10, 1919.

Research Council Budget for 1919–20, authorized and appointed April 1, 1919, Messrs. Leuschner (Chairman), Cross, Clevenger.

To express to Rockefeller Foundation the appreciation of the National Research Council for the support of National Research Fellowships in Physics and Chemistry, authorized and appointed April 15, 1919, Messrs. Hale (Chairman), Noyes, Millikan.

Budget—Expenses National Academy of Sciences and National Research Council, authorized and appointed April 30, 1919, President of National Academy (Chairman), Chairman of National Research Council, Treasurer of National Academy and National Research Council; May 27, 1919, function enlarged to include securing of funds to meet the needs of the National Academy and of the National Research Council, and the preparation of a budget apportioning such funds and other available funds. (Academy Committee.)

Removal of Offices of National Research Council, authorized and appointed May 8, 1919, Messrs. Walcott (Chairman), Cross, Dunn, Merriam.

To express to Retiring Treasurer Whitman Cross the appreciation of the National Research Council for his services, authorized and appointed May 8, 1919, Messrs. Woodward (Chairman), Leuschner, Washburn.

Scientific Men as Reserve Officers in the Reorganized Army, authorized March 18, 1919, appointed May 8, 1919, Messrs. Walcott (Chairman), Mathews, Leuschner.

Nominations of members at large of Executive Board (Joint Committee of Council of National Academy and Executive Board of Research Council), authorized April 30, 1919, appointed May 13, 1919, by Dr. Walcott; Messrs. Dunn (Chairman), Merriam, Yerkes; May 27, 1919, function enlarged to consider membership of Advisory Board.

Apportionment of space in Navy League Building, authorized and appointed May 20, 1919, Messrs. Mathews (Chairman), Leuschner, Yerkes.

Federal grants for research, authorized Jan. 14, 1919, appointed May 27, Messrs. Carty (Chairman), Dunn, Leuschner, Manning, Mees, Stratton, Walcott, Yerkes.

Representation of the United States at the International meetings at London and Brussels, July, 1919, authorized and appointed May 27, 1919, Messrs. Walcott (Chairman), Leuschner, Yerkes.

Committee on Patent Office, authorized and appointed July 31, 1917, Professor W. F. Durand (Chairman), Messrs. R. A. Millikan, S. W. Stratton. Reorganized December 14, 1917 as follows: Messrs. L. H. Baekeland, W. F. Durand (Chairman), Thos. Ewing, Frederick P. Fish, R. A. Millikan, E. J. Prindle, M. I. Pupin, S. W. Stratton. March 1918, Mr. Baekeland appointed Acting Chairman, approved at meeting of April 30, 1918. April 19, 1918, Mr. Reid Hunt added to the Committee. March 11, 1918, Mr. C. P. Townsend added to the Committee. Present Organization, Messrs, W. F. Durand (Chairman), L. H. Baekeland (Acting Chairman), Thos. Ewing, F. P. Fish, R. Hunt, R. A. Millikan, E. J. Prindle, M. I. Pupin, S. W. Stratton, C. P. Townsend. (*Adopted.*)

Moved: That the matter of preparation and publication of History of Research Activities in Science in this country during the war be referred to the Research Information Service. (*Adopted.*)

The Committee on Organization of Administration, Mr. Leuschner, chairman, submitted the following office organization for the National Research Council, which was approved as presented.

Office Organization of National Research Council

I. Executive Staff of the Board:
   1. Chairman of the Council
   2. Secretary of the Council
   3. Treasurer of the Council
   4. Chairman and other executive officers of Divisions

II. Technical Staff:
   1. Scientific Associates
   2. Assistants to Officers
   3. Division Secretaries

III. Business Staff:
1. Bursar
2. Chief Clerk

IV. Clerical Staff:
1. Secretaries to Chairmen
2. Division Clerks
3. Stenographers
4. General Clerks
   a. Draughtsmen
   b. Special or Head of c, d, e.
   c. Bookkeeper
   d. Typists
   e. Filing

V. Miscellaneous Employees:
1. Superintendent of Building
2. Telephone Operators
3. Messengers
4. Watchmen or Guards
5. Police workers

Moved: That in the absence of a superior executive officer the Secretary of the Division, exercising executive functions, be designated as "Executive Secretary." (*Adopted.*)

The Secretary presented a joint memorandum from the Committee on Organization of Administration and from the Budget Committee, regarding the salary list and bonuses for the year commencing July 1. The matter was left over for further consideration and the Secretary was requested to send a copy of the proposed salary and bonus schedules to the heads of Divisions and to present a further report at the next meeting of the Interim Committee.

Considering the question of expenses of members in attendance at meetings of the Executive Board and Executive Committees of the Divisions, it was

Moved: That members of the Executive Board residing out of the city of Washington shall be allowed their transportation expenses and in addition, expenses, not to exceed $6 per day, for maintenance during their attendance at meetings of the Executive Board, and that members of the Executive Committees of the Divisions shall be allowed transportation and maintenance expenses on the same basis as members of the Executive Board or only transportation expenses, at the discretion of the Division concerned.* (*Adopted.*)

In behalf of the Committee on Representation of the United States at the International Meetings at London and Brussels, July, 1919, Messrs, Walcott (Chairman), Leuschner, and Yerkes, Mr. Leuschner reported that a cablegram had been received from Mr. Mendenhall, Scientific Attaché at London, containing a provisional program of meetings; that in accordance with this schedule, meetings of the International Research Council, of the proposed International Astronomical, Chemical and Geophysical Unions, and conferences to discuss the question of internationl organizations in Medicine, Mathematics, Geology, Biology, and Physics, and conferences on International Patents, and

* This motion was subsequently amended. It will appear in the amended form in the printed minutes of a later meeting.

North Atlantic Fisheries, would begin at Brussels on July 18, 1919, and continue until July 30, 1919, and that a preliminary meeting of the International Chemical Union would be held at London beginning July 15, 1919. The Committee, which was given power to act, reported, further, that it had received nominations of delegates to all of these meetings and conferences from the proper sources, and submitted the names of representatives of the National Academy of Sciences and of the National Research Council to the various meetings and conferences, with the recommendation that proper credentials be issued to them by the President of the National Academy of Sciences, subject to the concurrence of the Foreign Secretary of the National Academy.

Meetings of International Research Council and of Affiliated Organizations at Brussels, Beginning July 18, 1919

PRECEDED BY MEETING OF INTERNATIONAL CHEMICAL UNION, LONDON, BEGINNING JULY 15

DELEGATES FROM THE UNITED STATES OF AMERICA

International Research Council

W. W. Campbell, *Chairman*

W. W. Campbell, Chairman of Amer. Del., International Astronomical Union
H. M. Howe, Scientific Attaché at Paris, also representing Engineering
C. E. Mendenhall, Scientific Attaché at London, also representing Physics
H. S. Washington, Scientific Attaché at Rome, also representing Geology
Major Wm. Bowie, Chairman of Amer. Del., International Geophysical Union
E. W. Washburn, Chairman of Amer. Del., International Chemical Union
W. S. Thayer, Representing Medicine
John C. Penny, Representing Patents
..... Representing Mathematics
Maj. Doug. W. Johnson, Representing Geography
H. F. Moore, Representing Biology and Fisheries

Astronomical Union

W. W. Campbell, *Chairman*

W. S. Adams
S. I. Bailey
Benjamin Boss
W. S. Eichelberger
Major Philip Fox
W. J. Humphreys
S. A. Mitchell
F. R. Moulton
H. N. Russell
Frank Schlesinger
C. E. St. John
F. H. Seares
Joel Stebbins

Geophysical Union

Major Wm. Bowie, *Chairman*

L. A. Bauer
H. C. Graves
A. O. Leuschner
G. W. Littlehales
C. F. Marvin
H. F. Reid
Capt. Edward Simpson
J. T. Watkins

Alternates: W. J. Humphreys, J. F. Hayford, W. J. Peters.

Chemical Union

E. W. Washburn, *Chairman*

Lt. Col. Edward Bartow — Julius Stieglitz
F. G. Cottrell — H. S. Washington
Chas. L. Parsons

Alternates: Lt. Col. A. B. Lamb, Lt. Col. Jas. F. Norris

Medicine

W. S. Thayer, *Chairman*, Geo. W. Crile, F. P. Gay, C. L. Gibson, W. H. Howell, Victor C. Vaughn

Mathematics

J. L. Coolidge

Geology

H. S. Washington

Geography

Major Douglas W. Johnson

Biology

H. F. Moore

Alternates: R. P. Bigelow, R. E. Coker

Physics

C. E. Mendenhall, S. W. Stratton

Patents

John C. Penny

Fisheries

H. F. Moore

Moved: That the report of the Committee on Representation of the United States at the International Meetings at London and Brussels, July, 1919, be approved and that the appointments of the delegates named be confirmed. (*Adopted.*)

The Chairman presented the following letter from the Adjutant General of the Army:

Chairman, National Research Council, New York, N. Y.

DEAR SIR: The report of Lieut. Colonel R. A. Millikan, Chairman, Physical Science Division of your Council, dated April 18, 1919, in which he states that the fund of fifteen thousand dollars originally allotted for research and development of a centrifugal gun is about exhausted and recommends that the Army take over further development of this type of ordnance has been given due consideration.

As a result of this investigation, the Secretary of War has directed that further development in connection with this subject be placed in the hands of the Inventions Section; War Plans Division, General Staff, and requests that the models, drawings, specifications and all data you may have in connection with the centrifugal gun be turned over to that section.

Arrangements will be made by the Inventions Section for the transfer of such skilled mechanics now employed by you at Pittsburgh as may be desirable for duty at the Bureau of Standards where future development of the centrifugal gun will take place.

Very truly yours,

[Signed] P. C. HARRIS,
The Adjutant General.
Per: J. C.

Moved: That the transfer of the models, drawings, etc., related to the development of a centrifugal gun be referred to the Chairman of the Division of Physical Science with request that he carry out the order of the Adjutant General of the Army. (*Adopted.*)

Moved: That the Council subscribe to the publication *Science* for the use of its members. (*Adopted.*)

Moved: That ten copies of the minutes and reports accompanying the minutes of the Divisions be sent to the Research Information Service, five for the use of the Washington office and five for the foreign offices. (*Adopted.*)

The Chairman presented the following nominations from the President of the American Psychological Association for membership in the Division of Anthropology and Psychology:

W. D. Scott, Scott Company, Drexel Building, Philadelphia, Pa.

E. L. Thorndike, Professor of Educational Psychology, Teachers' College, Columbia University, New York City.

Raymond Dodge, Professor of Psychology, Wesleyan University, Middletown, Conn.

James R. Angell, Chairman, National Research Council.

G. M. Whipple, Carnegie Institute of Technology, Pittsburgh, Pa.

C. E. Seashore, Head of Dept. of Philosophy and Psychology, University of Iowa, Iowa City, Ia.

Moved: That the names of Messrs. W. D. Scott, E. L. Thorndike, Raymond Dodge, James R. Angell, G. M. Whipple and C. E. Seashore be recommended to the President of the National Academy of Sciences for appointment as members of the National Research Council, with the request that they be assigned to the Division of Anthropology and Psychology. (*Adopted.*)

Moved: That as soon as, in accordance with the plan of organization of the Division of Anthropology and Psychology adopted May 27, 1919, the six members nominated by the American Psychological Association shall have nominated the remaining three psychologists, in conference with the Executive Board, the nine members representing Psychology may organize as a Section in Psychology of the Division and elect a Chairman of the Section and proceed with its work, pending the complete organization of the Division of Anthropology and Psychology. (*Adopted.*)

After consideration of a request of the Engineering Foundation that the National Research Council suggest means of furthering the study of problems of industrial employment, particularly the mental problems of industry, it was

Moved: That a committee consisting of representatives of each of the following divisions (Anthropology and Psychology, Educational Relations, Engineering, Industrial Relations, and Medicine) and the Chairman of the National Research Council who shall serve as a chairman of the committee be appointed by the Chairman of the Council to consider means of furthering the study of problems of Industrial employment in accordance with the request of the Engineering Foundation and to formulate a plan for presentation to the Foundation. (*Adopted.*)

The Chairman reported that Major R. G. Hussey, Acting Chairman of the Division of Medical Sciences, would be able to give only part of his time to the Nationl Research Council after his discharge from the Army, June 9.

The Secretary reported that the organizing meeting of the Division of Industrial Relations was held on Wednesday, June 11, 1919, at the Engi-

neering Society's Building, New York, and that the following actions were taken:

1. By lot, the terms of the 12 elected members of the Division were determined as follows:
One year, Carty Dunn, Washburn, and Whitney.
Two years, Baekeland, Johnston, Mees, and Townsend.
Three years, Flinn, Howe, Rautenstrauch, and the twelfth member, not yet elected.

2. The following officers were elected: Chairman, John Johnston, Vice-Chairman, Harrison E. Howe; Executive Committee, the Chairman and the Vice-Chairman ex officio, C. E. K. Mees, G. K. Burgess and Alfred D. Flinn.

3. It was voted to promote the establishment of an alloys research association, confirming action previously taken by the Industrial Research Section.

4. It was voted that when an alloys research association shall have been incorporated, it shall undertake the conduct of the research.

5. It was voted that four members of the Division of Industrial Relations, Howe, Rautenstrauch, Washburn, and Burgess, be appointed a committee to formulate a plan for an alloys research, and to visit users and others interested in alloys and confer with them concerning the formation of an association for conducting research.

6. It was the sense of the meeting that the Alloys Research Committee, while promoting this research, should investigate also the feasibility of promoting researches in refractories and in metal cutting. (*Adopted.*)

The Acting Chairman of the Division of Chemistry and Chemical Technology presented for approval the following personnel of the Committee on Ceramic Research:

A. V. Bleininger, Chairman ex officio, Bureau of Standards, Pittsburgh, Pa.
R. B. Sosman, Geophysical Laboratory, Washington, D. C.
Homer F. Staley, Bureau of Standards, Washington, D. C.
Arthur L. Day, Corning Glass Works, Corning, N. Y.
E. W. Washburn, Department of Ceramic Engineering, Univ. of Illinois. (*Approved.*)

In behalf of the Division of Chemistry and Chemical Technology, the Acting Chairman of that Division presented the following request:

In accordance with resolutions adopted at the meeting of the Executive Committee of the Division of Chemistry and Chemical Technology on June 3, 1919, the Division asks for an appropriation of $7000, to be used in carrying out a program for stimulating and organizing coöperative research in Chemistry. The plan approved by the Executive Committee of the Division includes the calling of conferences of investigators working along similar lines. The program of work for each such conference will be laid out carefully in advance by the Chairman of the Division, after correspondence or personal conference with the interested investigators. It is hoped that approximately five such conferences can be planned for and held during the coming year and it is estimated that the cost of holding these five conferences will be approximately $7000.

Moved: That the request of the Division of Chemistry and Chemical Technology for $7000 to carry out the plans for stimulating and organizing cooperative research in Chemistry be referred to the Budget Committee to be considered with other plans of a similar nature. (*Adopted.*)

On recommendation of the Acting Chairman of the Division of Chemistry and Chemical Technology, it was

Moved: That authority be given to the Division of Chemistry and Chemical Technology to have printed, at the expense of their maintenance fund, stationery for the Committee on Explosives, the Committee on Sewage Disposal, the Committee on Ceramic Research, and the Committee on Synthetic Drugs. (*Adopted.*)

With reference to the expenses of delegates to the international meetings to be held in London and Brussels in July, 1919 who are now in Europe, it was

Moved: That the Budget Committee be asked to consider and make financial arrangements to cover the expenses of delegates to the international meetings to be held in London and Brussels in July, 1919, who are now in Europe. (*Adopted.*)

The meeting adjourned at 12.30 p.m. to meet again at 9.15 a.m., Wednesday, June 18.

The Adjourned meeting of the Interim Committee was called to order at 9.15 a.m. Wednesday, June 18, at the office of the National Research Council.

Present: Messrs. Leuschner, McClung, Merriam, Ransome, and Washburn.

The Secretary submitted the following recommendation of the Acting Chairman of the Division of Geology and Geography:

The Division of Geology and Geography request authority for the publication of a small four to six page folder indicating the organization of the Division to be sent to all members of societies represented on the Division. The manner of publication should be in accord with the system of publication of publicity leaflets to be issued by the Council.

Moved: That the printing of a folder indicating the organization of the Division of Geology and Geography and the principle of the publication of folders of uniform size and content be approved. (*Adopted.*)

On recommendation of the Chairman of the Division of Biology and Agriculture it was

Moved: That the Committee on Instruction in Universities, of the Division of Biology and Agriculture, consisting of Messrs. Bradley M. Davis and C. E. McClung, be continued, and that this committee be included in the membership of the Committee of that Division on Educational Relations as a sub-committee. (*Adopted.*)

Moved: That the question of a liaison member on the Division of Educational Relations from the sub-committee on Instruction in Universities of the Committee on Educational Relations of the Division of Biology and Agriculture be referred to the Division of Educational Relations for consideration and report. (*Adopted.*)

Moved; That the whole question of coordination of the Divisions of Science and Technology with the Division of Educational Relations be referred to the Division of Educational Relations for consideration and report, with particular reference to the Committee on Educational Relations of the Division of Biology and Agriculture. (*Adopted.*)

Moved: That the Committee on Salting Fish in Southern Climates, of the Division of Biology and Agriculture, consisting of Messrs. H. F. Moore, and B. E. Livingston, be discontinued. (*Adopted.*)

Moved: That the Advisory Board of American Plant Pathologists, consisting of Messrs. G. R. Lyman, H. W. Barre, H. P. Barss, H. S. Jackson, P. A. Murphy, and C. R. Orton, be recognized as a Committee on Plant Pathology representing the Division of Biology and Agriculture, and that it be continued with Mr. G. R. Lyman as Chairman. (*Adopted.*)

Moved: That a Committee of the Division of Biology and Agriculture on Cooperation and Coordination be appointed; three members to be appointed by the Chairman of the

Division with authority to enlarge the committee so that it will include not more than seven members. (*Adopted.*)

The Chairman of the Division of Biology and Agriculture presented the names of Messrs. F. R. Lillie (Chairman), G. R. Lyman and J. R. Murlin to act on this committee.

Moved: That a Special Committee of three of the Division of Biology and Agriculture be appointed to consider ways and means of securing and publishing current problems in biology, and to make recommendations to the Executive Committee. (*Adopted.*)

The Chairman of the Division of Biology and Agriculture presented the names of Messrs. G. N. Collins (Chairman), Barrington Moore and P. J. Parrott to serve on this committee. (*Approved.*)

Moved: That a committee of at least five, of the Division of Biology and Agriculture, be appointed to consider the general question of Biological Investigations in Tropical America and report back to the Division. (*Adopted.*)

The Chairman of the Division of Biology and Agriculture presented the names of Messrs. A. S. Hitchcock (Chairman), L. R. Jones, Barrington Moore, Wilfred Osgood and H. N. Whitford to serve on this committee. (*Approved.*)

Moved: That Mr. Vernon L. Kellogg be nominated as tenth member-at-large of the Division of Biology and Agriculture for a period of one year, with recommendation to the President of the National Academy of Sciences that he be appointed a member of the National Research Council and assigned to that Division. (*Adopted.*)

Moved: That the recommendation of the Division af Biology and Agriculture for the appointment of a Committee of that Division on the Study of Oceanography be approved. (*Adopted*)

The Chairman of the Division of Biology and Agriculture stated that in his opinion it was desirable that the Chairmen of Divisions be present at the meetings of other Divisions, and recommended further that the minutes of the Divisions be exchanged.

Moved: That the suggestion of the Chairman of the Division of Biology and Agriculture that Chairmen of Divisions be present whenever possible at the meetings of other Divisions be specifically approved, and that the minutes of the Divisions be exchanged. (*Adopted.*)

Moved: That the matter of acceptance of alterations made by the Navy League on the building recently leased by the National Research Council at 201 Sixteenth Street be referred to the Committee on Space, with power to act. (*Adopted.*)

The Chairman of the Council brought up the question of the organization of the Division of Government Relations. It was

Moved: That the President of the National Academy of Sciences be requested to confer with the heads of those departments of the Government which, by action of the Executive Board of the National Research Council and the Council of the National Academy of Sciences, are represented on the Government Division, with a view to selecting representatives of these Departments to be included in the Government Division; that the President of the National

Academy of Sciences be requested to invite the Secretary of the Smithsonian Institution to serve as Chairman of the Government Division; and further that the President of the Academy be requested to present to the President of the United States the personnel of the Government Division to be designated as members of the National Research Council in the Government Division. (*Adopted.*)

The Secretary presented a provisional draft of a bulletin of the National Research Council containing a full description of its organization including the membership of its Divisions and Committees.

Moved: That the draft of the organization of the National Research Council, including the membership of its Divisions and Committees, be printed, subject to the regulations relating to the printing of bulletins adopted at the meeting of the Executive Board on June 10, 1919. (*Adopted.*)

Moved: That Mr. S. L. G. Knox be appointed Assistant to the Scientific Attachés at Paris and Rome, without salary, from April 15 to June 30, 1919, and to Sept. 30, 1919, if Attachés are continued. (*Adopted.*)

Moved: That Mr. Donald J. Cowling, President of Carleton College, be nominated to represent the Association of American Colleges in the Division of Educational Relations in the National Research Council, with recommendation to the President of the National Academy of Sciences that Mr. Cowling be appointed a member of the National Research Council and assigned to the Division of Educational Relations. (*Adopted.*)

The meeting adjourned at 10.45 a.m.

PAUL BROCKETT, *Assistant Secretary.*

REPORT OF THE ANNUAL MEETING OF THE ACADEMY

PREPARED BY THE HOME SECRETARY

The Annual Meeting of the National Academy of Sciences was held at the Smithsonian Institution, Washington, D. C., April 28, 29, and 30, 1919, with President Walcott presiding.

Seventy members were present as follows: C. G. Abbot, Aitken, Ames, Benedict, Birkhoff, Boas, Bumstead, Cannon, Cattell, F. W. Clarke, J. M. Clarke, Conklin, Cross, Cushing, Dall, Davenport, Davis, Day, Dickson, Fewkes, Flexner, Forbes, Hale, E. H. Hall, Hayford, Hillebrand, Holmes, Howard, Howe, Iddings, Jennings, Jewett, Kasner, Langmuir, Leuschner, Loeb, Lusk, Mayor, Mendel, C. H. Merriam, J. C. Merriam, Millikan, Morgan, Moulton, E. L. Nichols, E. F. Nichols, A. A. Noyes, W. A. Noyes, H. F. Osborn, T. B. Osborne, Pearl, Ransome, Reid, Rosa, Russell, Schlesinger, Schuchert, Erwin F. Smith, Stieglitz, Stratton, Thorndike, Ulrich, Van Vleck, Vaughan, Walcott, Webster, Wheeler, D. White, H. S. White, Woodward.

BUSINESS SESSIONS

The Annual Report of the President, containing that of the Treasurer for 1918 in printed form was presented, accepted and distributed to the members.

The following assignments of Biographical Memoirs were announced: Memoirs of Geo. Francis Atkinson to N. L. Britton, of George F. Becker, to A. G. Webster, of Maxime Bôcher to Wm. E. Story, of Edward C. Pickering to H. N. Russell, of Wallace C. Sabine to Edwin H. Hall, and of Charles R. Van Hise to T. C. Chamberlin.

Changes in personnel of sections and committees were announced as follows:

Local Committee: F. L. RANSOME, chairman; M. T. BOGERT, A. O. LEUSCHNER, C. H. MERRIAM, E. F. NICHOLS, E. B. ROSA.

Henry Draper Fund: W. W. CAMPBELL to succeed himself, term expiring in 1924.

J. Lawrence Smith Fund: E. W. MORLEY, to succeed himself, term expiring in 1924. A. O. LEUSCHNER to fill the unexpired term of E. C. Pickering, expiring in 1920.

Comstock Fund: W. R. WHITNEY to succeed A. A. Noyes, term expiring in 1924.

Marsh Fund: J. C. MERRIAM to succeed E. H. Moore as chairman and member, term expiring in 1922.

Murray Fund: W. M. DAVIS, to succeed himself, term expiring in 1922.

Marcellus Hartley Fund: A. A. NOYES, chairman and member, to succeed G. F. Becker, term expiring in 1922. S. W. STRATTON to succeed W. F. Hillebrand, term expiring in 1922.

REPORTS FROM OFFICERS OF THE ACADEMY

The Home Secretary presented the following report, which was accepted.

April 28, 1919.

The President of the National Academy of Sciences,
Washington, D. C.

SIR: I have the honor to present the following report of the Acting Home Secretary on the publications and membership of the National Academy of Sciences for the year ending April 30, 1919.

The exigencies of war have retarded printing in Washington and for that reason no scientific memoirs have been published during the year. Publication has been taken up again, however, and four memoirs are now in preparation:

"The Complete Classification of the Triad Systems in Fifteen Elements," by H. S. White, F. N. Cole, and Miss L. D. Cummings, received in manuscript on June 20, 1917 and sent to the Public Printer to be published as Volume XIV, Second Memoir.

"Tables of the Minor Planets—Discoveries by James C. Watson, Part 2: On Von Zeipel's Theory of the Perturbations of the Minor Planets of the Hecuba Group," by A. O. Leuschner, A. E. Glancy, and S. H. Levy, received in manuscript on January 7, 1919, and sent to the Public Printer to be published as Volume XIV, Third Memoir.

"Minor Constituents of Meteorites," by George P. Merrill, received in manuscript on May 11, 1918 and sent to the Public Printer to be published as Volume XIV, Fourth Memoir.

"Tables of the Exponential Function and of the Circular Sine and Cosine to Radian Argument," by C. E. Van Orstrand, received in manuscript May 24, 1918 and sent to the Public Printer to be published as Volume XIV, Fifth Memoir.

No Biographical Memoirs have been published, owing to pressure of war work, but the following biographies have been sent to the printer and are near completion:

Cleveland Abbe, by W. J. Humphreys, received in manuscript November 7, 1917.

Lewis Boss, by Benjamin Boss, received in manuscript March 20, 1917.

William Bullock Clark, by John M. Clarke, received in manuscript January 2, 1918.

James Mason Craft, by Charles R. Cross, manuscript received November 10, 1918.

James Dwight Dana, by L. V. Pirsson, received in manuscript November 12, 1917.

Arnold Hague, by J. P. Iddings, received in manuscript August 2, 1918.

Eugene Woldemar Hilgard, by F. Slate, Jr., received in manuscript October 11, 1918.

Alpheus Spring Packard, by T. D. A. Cockrell, received in manuscript October 16, 1918.

Benjamn Osgood Peirce, by E. H. Hall, received in manuscript November 20, 1917.

With the publication of these memoirs Volume VIII of the Biographical Memoirs will have been published and ready for distribution, while two thousand copies of the Third Annual Report of the National Research Council will be issued in a few days. The PROCEEDINGS of the Academy have been published regularly and have reached the third number of the fifth volume.

Six members have died since the last meeting:

George Francis Atkinson, elected 1918, died November 14, 1918.

George F. Becker, elected 1901, died April 20, 1919.

Maxime Bôcher, elected 1909, died September 12, 1918.

Edward C. Pickering, elected 1873, died February 3, 1919.

Wallace C. Sabine, elected 1917, died January 10, 1919.

Charles R. Van Hise, elected 1902, died November 19, 1918.

One foreign associate, Sir William Crookes, elected in 1913, died April 4, 1919.

There are now on the membership list 164 active members, 1 honorary member, and 35 foreign associates.

C. G. ABBOT, *Acting Home Secretary.*

The Foreign Secretary presented a report on the work of his office during the past year, stating that it largely had to do with the organization of the International Research Council, and that this was fully reported on in the work of the National Research Council.

Moved: That the Report of the Foreign Secretary be accepted, and the action reported therein of the delegates to the International Research Council be approved. (*Adopted.*)

REPORTS FROM COMMITTEES ON TRUST FUNDS

A report was received from the Directors of the Bache Fund, signed by Edwin B. Frost (Chairman) stating that since the annual meeting of the Academy in April, 1918, grants Nos. 210–213 as announced in the PROCEEDINGS, p. 492, below) had been made. (A provisional grant of $1000 was made for another research, but the applicant had meantime started on his trip of exploration and has not been heard from since, so that it is not certain that the money will be required.) Reports on these and previous grants have been submitted by the recipients, to wit:

The recipient of a grant made some years ago, whose work had not yielded results entirely to his satisfaction, offered to return the money which he had expended, with interest. The directors, however, unanimously declined to accept such return, regarding it as establishing a very unwise precedent which would imply that the recipient of a grant might be personally responsible if a research seriously prosecuted did not yield the results hoped for by him.

No. 202. W. C. ALLEE, Lake Forest, Illinois. The survey of the effect of the re-agents on reactions to light of Mayfly Nymphs. Results published, *Biol. Bul.*, 32, 93–97; and *J. Exper. Zoöl.*, 26, 423–459. Further work in progress on reversals to light; cause and effects of aggregation in certain Arthropods; effect of cyanides on Arthropods.

No. 203. JOSEPH P. IDDINGS, Brinklow, Md. The work continues and will not be finished for some time yet.

No. 205. T. H. GOODSPEED, Berkeley, Cal. Experiments on Nicotiana, Publication of the final results has been delayed by military and civilian service of the collaborators.

No. 207. T. H. GRONWALL. Mathematical investigations. Preliminary results published in these PROCEEDINGS 5, 22–24, January, 1919, under the title, "A Theorem of Power Series with an Application to Conformal Mapping." Three notes embodying further results are in preparation and will soon be sent to the editor of the PROCEEDINGS.

No. 208. A. F. SHULL, Ann Arbor, Mich. Research is concluded on (1) Cell inconstancy in hydatina; and (2) Relative effectiveness of food, oxygen, etc. in causing or preventing male production. Results published (1) *J. Morph.*, 30, No. 2, March 1918; (2) *J. Exper. Zool.*, 26, No. 3, Aug. 1918. Research is still in progress on nuclea volume in relation to life cycle of hydatina; also on phenomena of maturation in relation to life cycle of hydatina; and on rate of metabolism in relation to life cycle of aphids.

No. 209. CECIL K. DRINKER, Boston. In addition to the first paper, reported last year three others will be sent to the *J. Exper. Medicine* during the coming year, based on the study of material which has been accumulated with the aid of this grant.

No. 210. W. J. ATWELL, Buffalo, N. Y. A research on the development of human hypophysis cerebri is in progress. Three models have been completed by the Bron wax-late method, showing hypophysis of 10 mm., 16 mm., 30 mm. human embryos.

No. 211. GEORGE H. SHULL, Princeton, N. J. The studies on heredity in Shepherd's-purse and Evening Primroses are being carried on with a minimum of labor and would have been impossible without the grant.

The American collaborators of the Nomenclator Animalium Generum et Subgenerum have been paid the amounts due for their work.

A report was received from the Committee on the Henry Draper Fund, signed by W. W. Campbell (Chairman) as follows:

The Committee has unanimously recommended to the Council that the Henry Draper Gold Medal be awarded to Professor Charles Fabry of the University of Marseilles, in recognition of his researches in Physics and Astronomy, chiefly by means of interferometers.

There have been no applications received for grants from the Henry Draper Fund in support of research during the past year. This is probably due in large measure to the fact that many investigators have been engaged upon war problems and that investigators remaining at home have not planned for extensions of instrumental means.

The total amount of income available for the encouragement of research was $2234.94 on April 1, 1919. Of this sum $382.44 was cash on hand and $1952.50 was invested in securities.

A report was received from the Trustees of the Watson Fund, signed by A. O. Leuschner (Chairman), G. C. Comstock and W. L. Elkins, stating that

grants Nos. 18–20 (as announced below, p. 492) were recommended and that reports of progress on previous grants were as follows:

No. 15. A grant of $300 was made in April, 1917, to Professor HERBERT C. WILSON of Carleton College, Northfield, Minn,, for the continuation of the photographic determination of the positions of minor planets. During the past year about 60 plates of minor planets have been secured, but measurement of the positions has been interrupted by loss of assistants. The results obtained under previous grants have been published in Publications of the Goodsell Observatory of Carleton College, Numbers 5 and 6, 1917–18 under the title, "Photographic Observations of Asteroids," by H. C. Wilson, C. H. Gingrich,and Julia M. Hawkes (No. 6).

No. 16. A grant of $500 was made to Professor JOHN A. MILLER, Director of the Sproull Observatory of Swarthmore College, Pennsylvania, for the employment of an assistant in measuring and reducing plates for the determination of parallaxes. This fund is being paid to Miss Carolyn H. Smedley, Research Assistant in the Observatory. In the fall she also aided in studying the corona of the eclipse of 1918. The sum of $500 is only part of her salary. The observatory has recently put into press fifty new parallaxes. A great number of series are in process of measurement. Between twenty and twenty-five additional parallaxes are ready for publication.

A report was received from the Committee on the J. Lawrence Smith Fund signed by E. W. Morley (Chairman) stating that reports on previous grants were as follows:

No. 4. Professor C. C. TROWBRIDGE, of the Department of Physics, Columbia University, New York, has received grants amounting to $1400 to aid in the study of luminous trains of meteors. His lamented and untimely death in June last has put an end to this investigation.

An unfinished paper on the spectra of luminous trains has been completed from his notes by a research assistant familiar with the whole investigation, and is now ready for submission to the Academy. Two other papers are to be completed in the same way: one contains a summary of theories hitherto advanced in explanation of meteor trains, and the other discusses certain auroral phenomena and their relation to theories concerning meteor trains.

Two other parts of Professor Trowbridge's research have probably not gone so far that they can be completed without further investigation. One concerns the drift and diffusion of meteor trains as bearing on the phosphorescent gas theory; the other concerns the height of meteor trains and its relation to the height of the atmosphere. A large amount of classified information, arranged for convenient reference, has been collected by Professor Trowbridge, which it is hoped will be utilized by some one who may interest himself in these or cognate matters.

The department of physics in Columbia University has inquired what disposition shall be made of this material, and the committee suggest that it be forwarded to the Secretary of the Academy for preservation till it may become useful. We have also requested the research assistant of Professor Trowbridge to prepare a paper stating the nature and extent of th e information contained in this material, which will soon be ready.

No. 9. Professor S. A. MITCHELL, University of Virginia, University, Va., has received grants amounting to $1500 to aid in securing observations of meteor paths and radiants, and in computing orbits where the observations suffice. During the last year, war-time activities have interrupted this valuable work. It is now resumed, and the unexpended balance of the grant may well be sufficient for a time.

There is now $850.39 cash in hand, as well as $2032.50 invested income, making $2882.89 available for grants.

A report was received from the Directors of the Benjamin Apthorp Gould Fund, signed by F. R. Moulton, E. E. Barnard and R. S. Woodward, stating that on April 1, 1919, the total income balance of the Gould Fund was $7028.46, of which $1773.46 was in cash and $5255 in interest-bearing securities; and that since April 1, 1919, a grant of $500 had been made to Benjamin Boss for the support of the *Astronomical Journal*.

A report was received from the Directors of the Wolcott Gibbs Fund, signed by C. L. Jackson, Edgar F. Smith, and T. W. Richards stating that the unexpended income of the fund amounted to $622.76, of which $500 had been invested temporarily in Liberty Bonds; that no award had been made; and that reports on previous awards were as follows:

No. 8. Professor R. L. DATTA, University College of Sciences, Calcutta, reports that in spite of hindrance from the war he has procured organic chemicals to the value of three-quarters of the grant, and that these have enabled him to carry on work described in two papers now ready for publication in the *Journal of the American Chemical Society*—"Iodination by Means of Nitrogen Iodide and Replacement of Iodine by Nitro Groups," by R. L. Datta and J. Lahire. This paper contains a careful study of the two reactions including the description of seven new compounds. "The Replacement of Sulphuric Groups of Chlorine and the Preparation of Organic Chloro-derivatives," by R. L. Datta and H. K. Miller. This paper contains a careful study of this reaction.

No reports were received from Professor W. B. Harkins, (Nos. 4 and 7), or from Professor G. P. Baxter, (No. 6).

(No report was presented from the Committee on the Marcellus Hartley Fund, owing to the recent death of the Chairman, Dr. George F. Becker.)

A report was received from the Committee on the Marsh Fund, signed by E. H. Moore (Chairman), stating that the condition of the Fund was

Total capital April 1,1919	$19,500.00
In addition, cash	375.47
Two Liberty bonds	150.00
Accrued income to be added May 1, 1919, about	227.00

By the addition of $500 from balance and income the capital is to be raised to $20,000 February 1, 1920. Reports on previous grants are as follows

No. 1. Dr. JOHN M. CLARKE, Albany, New York: "Mutualism, Symbiosis and Dependent Life among Animals of Geologic Time." In view of the difficulty of completing this investigation under war conditions Dr. Clarke was authorized to make use of part of this Grant for clerical work in the preparation for the Academy of the James Hall biography. Dr. Clarke reports—First—the original investigation is progressing favorably. "Study of geological evidences of parasitism and dependence has proceeded as opportunity permitted. Surveys and selections have been made of the material in several of the larger museums. Special collecting has been done, a good degree of careful preparation made of the material and a considerable number of enlarged stereo photographs made." Second—"The Hall Memoir, which has involved the reading and extraction of 10,000 letters and many other records, is now approaching conclusion, having been brought up to the year 1880."

No. 2. M. Ferdinand Canu, Versailles, France, "Early Tertiary Bryozoa of North America." This grant was to further the completion of investigations in progress in coöperation with Dr. R. S. Bassler of the United States National Museum, who reports: "This work is

now in press as Bulletin 106 of the United States National Museum, consisting of 162 quarto plates and a correspondingly large number of text figures and pages of text. With this assistance we have also completed a study on 'Early Tertiary Cyclostomatous Bryozoa,' which when printed, will amount to about 100 pages of text and 30 to 40 plates."

A report was received from the Committee on the Murray Fund, signed by Wm. H. Dall (Chairman), stating that the total amount of income available from this fund according to the Treasurer, is $916.91; of which $516.91 was in cash and $400 in Liberty Bonds; and that the Committee duly reported their recommendation in regard to the award of the medal which was approved by the Council, and would be carried out at the dinner on April 29, 1919.

GENERAL BUSINESS

A report by the Auditing Committee, C. G. Abbot, L. O. Howard, and David White, stating that the regular financial statement of the Treasurer and the special account in support of the Division of Medicine of the National Research Councils had been duly audited and found correct.

The following report of the Editorial Board of the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES was received:

The Editorial Board reports as follows regarding its activities during the past year: Volume 4 of the PROCEEDINGS has been completed, and the numbers of Volume 5 are being regularly issued each month.

The articles in Volume 4 of the PROCEEDINGS may be summarized as follows: Mathematics, 9; Astronomy, 11; Physics and Engineering, 25; Chemistry, 5; Geology and Paleontology, including Mineralogy and Petrology, 9; Botany, 3; (see also Genetics); Zoology, including General Biology, 12, (see also Genetics); Genetics, 6; Physiology and Pathology, 10; Anthropology and Psychology, 1; a total of 91 articles. The division of these articles between members of the Academy and non-members is 39 and 52 respectively.

The list of institutions which have contributed three or more articles is as follows: Carnegie Institution, 15, divided as follows: Solar Observatory, 7; Nutrition Laboratory, 4; Geophysical Laboratory, 1; Marine Biology, 2; Station for Experimental Evolution, 1; Harvard University, 15; Brown University, 7; University of Illinois, 5; Bermuda Biological Station for Research, 4; University of California, 4; University of Chicago, 4; University of Pennsylvania, 4.

On April 28, 1919 the Editorial Board held its annual meeting, the following members being present: Messrs. Pearl, Wilson, Day, Hale, Clarke, Jennings, Lusk, Mayor, Millikan, A. A. Noyes, W. A. Noyes, Thorndike, and Wheeler. In regard to the general editorial policy of the PROCEEDINGS, it was held to be desirable to make the PROCEEDINGS, in so far as possible, a publication of permanent original, scientific value, in which duplication of publication should be avoided so far as was consistent with the general policy which has prevailed in the PROCEEDINGS throughout its existence of publishing short articles embodying a brief statement of the results of important researches which were eventually to be published in detail elsewhere. It was agreed that the rule of the PROCEEDINGS requiring prior publication should be waived in the case of summaries of an extended series of papers, some (if not all) of which had already appeared elsewhere, provided that the summary was so written as to be of practical use in enforcing the points made in individual papers and in attracting the attention of workers in related fields, thus making the summary in the PROCEEDINGS a real contribution to the subject.

It was agreed in general to adhere to the present policy of the PROCEEDINGS in retard to having the bulk of its contents made up of numerous short articles of first-class quality, fall ing in general under the 6-page limit. It was thought desirable, however, to continue the policy of accepting longer articles under special circumstances, 12 to 15 pages being regarded as a proper maximum length for such articles. It was agreed that the Managing Editor and the Chairman of the Board should have all reasonable freedom in exercising their judgment on the administration of policy as to length of articles in particular cases.

A special joint committee of the Editorial Board of the PROCEEDINGS on the one hand, and the National Research Council on the other hand, met and considered the general question of the future relations of the National Research Council and the PROCEEDINGS. The special committee was constituted as follows: For the Editorial Board: the Chairman, the Managing Editor, and Dr. Day; for the National Research Council: Doctors Hale, Merriam and Yerkes. The general policy worked out by this joint committee was agreed to by the Editorial Board. It was in effect this, that the PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES should become in a broader sense than had been true in the past, representative of the activities of the National Research Council, as well as of the National Academy. It was understood that the National Research Council should offer to the PROCEEDINGS as official communications of the Research Council of the National Academy such material (intended for publication as bulletins of the Council) as the Council considered to be of permanent scientific value in the PROCEEDINGS. It was felt that in view of the proposed enlargement of the scope of the PROCEEDINGS to represent the activities of the National Research Council that some changes in the typography of the PROCEEDINGS might be desirable and it was agreed that changes looking to the improvement of the PROCEEDINGS in this regard would be inaugurated as soon as agreement on the matter had been reached between the conferees from the two interested bodies.

Although no formal report can be made on the matter at this time, the Editorial Board is in possession of information which leads it to hope that the financial support of the PROCEEDINGS will be more adequately provided for in the near future. In this event, the Editorial Board expects to inaugurate, with the approval of the Council of the Academy, certain changes in details of policy which will be in the direction of more liberal arrangements between the PROCEEDINGS and its contributors, particularly in the matter of providing a certain number of free reprints to authors. The wisdom of such policy has always been clear to the Editorial Board, but the simple fact of lack of available funds in the past has made it impossible for the Board to carry out its wishes in this matter.

Respectfully submitted,
RAYMOND PEARL, *Chairman.*

The following organization of the National Research Council was presented and, upon motion, was adopted as a whole, with power of amendment vested in the Council of the National Academy of Sciences.

Organization of the National Research Council

Preamble

The National Academy of Sciences, under the authority conferred upon it by its charter enacted by Congress, and approved by President Lincoln on March 3, 1863, and pursuant to the request expressed in an Executive Order made by President Wilson on May 11, 1918, hereto appended, adopts the following permanent organization for the National Research Council, to replace the temporary organization under which it has operated heretofore.

Article I.—Purpose

It shall be the purpose of the National Research Council to promote research in the mathematical, physical, and biological sciences, and in the application of these sciences to engineer-

ing, agriculture, medicine, and other useful arts, with the object of increasing knowledge, of strengthening the national defense, and of contributing in other ways to the public welfare, as expressed in the Executive Order of May 11, 1918.

Article II.—Membership

Section 1. The membership of the National Research Council shall be chosen with the view of rendering the Council an effective federation of the principal research agencies in the United States concerned with the fields of science and technology named in Article I.

Section 2. The Council shall consist of

1. Representatives of national scientific and technical societies;
2. Representatives of the Government, as provided in the Executive Order;
3. Representatives of other research organizations and other persons whose aid may advance the objects of the Council.

Article III.—Divisions

Section 1. The Council shall be organized in Divisions of two classes:

A. Divisions dealing with the more general relations and activities of the Council;
B. Divisions dealing with related branches of science and technology.

Section 2. The initial constitution of the Divisions of the Council shall be as follows:

A. Divisions of General Relations:
   - I. Government Division.
   - II. Division of Foreign Relations.
   - III. Division of States Relations.
   - IV. Division of Educational Relations.
   - V. Division of Industrial Relations.
   - VI. Research Information Service.

B. Divisions of Science and Technology:
   - VII. Division of Physical Sciences.
   - VIII. Division of Engineering.
   - IX. Division of Chemistry and Chemical Technology.
   - X. Division of Geology and Geography.
   - XI. Division of Medical Sciences.
   - XII. Division of Biology and Agriculture.
   - XIII. Division of Anthropology and Psychology.

Section 3. The number of divisions and the grouping of subjects in Article III, section 2, may be modified by the Executive Board of the National Research Council.

Section 4. The Divisions of General Relations shall be organized by the Executive Board of the National Research Council (Article IV, section 2).

Section 5. To secure the effective federation of the principal research agencies in the United States, provided for in Article II, a majority of the members of each of the Divisions of Science and Technology shall consist of representatives of scientific and technical societies, chosen as provided for in Article V, section 2. The other members of the Division shall be nominated by the Executive Committee of the Division, approved by the Executive Board of the National Research Council, and appointed in accordance with Article V, section 4.

Section 6. The Divisions of the Council, with the approval of the Executive Board, may establish sections and committees, any of which may include members chosen outside the membership of the Council.

Article IV.—Administration

Section 1. The affairs of each Division shall be administered by a Chairman, a Vice-Chairman, and an Executive Committee, of which the Chairman and the Vice-Chairman shall be ex-officio members; all of whom shall be elected annually by the Division and confirmed by the Executive Board.

Section 2. The affairs of the National Research Council shall be administered by an Executive Board, of which the officers of the Council, the President and Home Secretary of the National Academy of Sciences, the President of the American Association for the Advancement of Science, the Chairmen and Vice-Chairmen of the Divisions of Science and Technology and the Chairmen of the Divisions of General Relations shall be ex-officio members. The Executive Board may elect additional members, not to exceed ten in number, who, if not already members of the National Research Council, shall be appointed thereto, in accordance with Article V, section 4.

Section 3. The officers of the National Research Council shall consist of a Chairman, one or more Vice-Chairmen, a Secretary, and a Treasurer, who shall also serve as officers of the Executive Board of the Council.

Section 4. The officers of the National Research Council, excepting the Treasurer, shall be elected annually by the Executive Board. The Treasurer of the National Academy of Sciences shall be ex-officio Treasurer of the National Research Council.

Section 5. The duties of the officers of the Council and of the Divisions shall be fixed by the Executive Board.

Article V.—Nominations and Appointments

Section 1. The Government bureaus, civil and military, to be represented in the Government Division, and the scientific and technical societies, to be represented in the Divisions of Science and Technology of the National Research Council, shall be determined by joint action of the Council of the National Academy of Sciences and the Executive Board of the National Research Council.

Section 2. Representatives of scientific and technical societies shall be nominated by the societies, at the request of the Executive Board, and appointed by the President of the National Academy of Sciences to membership in the Council and assigned to one of its Divisions.

Section 3. The representatives of the Government shall be nominated by the President of the National Academy of Sciences after conference with the Secretaries of the Departments concerned, and the names of those nominated shall be presented to the President of the United States for designation by him for service with the National Research Council.

Section 4. Other members of the Council shall be nominated by the Executive Committees of the Divisions, approved by the Executive Board, and appointed by the President of the National Academy of Sciences to membership and assigned to one of the Divisions.

Section 5. Prior to the first annual meeting of the Council following January 1, 1919, all Divisions shall be organized by appointment of their members in accordance with Article II and Article V, sections 1 to 4.

Section 6. As far as practicable one-third of the original representatives of each scientific and technical society and approximately one-third of the other original members of each of the Divisions of Science and Technology shall serve for a term of three years; one-third for a term of two years, and one-third for a term of one year, their respective terms to be determined by lot. Each year thereafter, as the terms of members expire, their successors shall be appointed for a period of three years.

Section 7. The Government representatives shall serve for periods of three years, unless they previously retire from the Government office which they represent, in which case their successors shall be appointed for the unexpired term.

Section 8. As far as practicable a similar rotation shall be observed in the appointment of the members of the Divisions of General Relations.

Article VI.—Meetings

Section 1. The Council shall hold one stated meeting, called the annual meeting, in April of each year, in the city of Washington, on a date to be fixed by the Executive Board. Other meetings of the Council shall be held on call of the Executive Board.

Section 2. The Executive Board and each of the Divisions shall hold an annual meeting, at which officers shall be elected, at the time and place of the annual meeting of the Council, unless otherwise determined by the Executive Board, and such other meetings as may be required for the transaction of business.

Section 3. Joint meetings of the Executive Board of the National Research Council and the Council of the National Academy of Sciences shall be held from time to time, to consider special requests from the Government, the selection of organizations to be represented in the National Research Council, and other matters which, in the judgment of the President of the National Academy, require the attention of both bodies.

Article VII.—Publications and Reports

Section 1. An annual report of the work of the National Research Council shall be presented by the Chairman to the National Academy of Sciences, for submission to Congress in connection with the annual report of the President of the Academy.

Section 2. Other publications of the National Research Council may include papers, bulletins, reports, and memoirs, which may appear in the Proceedings or Memoirs of the National Academy of Sciences, in the publications of other societies, in scientific and technical journals, or in a separate series of the Research Council.

The following communication from Mr. Whitman Cross, resigning the position of Treasurer, which he had held for eight years, was presented and accepted with regret, in view of the valuable services which Mr. Cross had rendered to the Academy.

April 21, 1919.

My dear Dr. Walcott:

I hereby respectfully tender my resignation as Treasurer of the National Academy of Sciences, to take effect on May first, or as soon thereafter as my successor can qualify. It has been a great pleasure to render to the Academy such service as I could as Treasurer during the last eight years. It is now necessary that I should be able to devote myself exclusively to the completion of work which has been in progress for many years in connection with the United States Geological Survey.

With high appreciation of the opportunity for connection with the work of the Academy for so many years, I am, very sincerely yours,

WHITMAN CROSS.

The Home Secretary was requested to transmit the thanks of the Academy to the Signal Corps of the United States Army, the Smithsonian Institution, the Bureau of Standards, and to the Cosmos Club, for the courtesies extended during the meeting.

ELECTION OF OFFICERS AND MEMBERS

C. G. ABBOT was unanimously elected Home Secretary.

F. L. RANSOME was unanimously elected Treasurer.

J. J. CARTY, H. H. DONALDSON, and RAYMOND PEARL were elected members of the Council.

The following persons were elected as new members of the Academy.

JOSEPH BARRELL, Yale University, New Haven, Conn.
GARY NATHAN CALKINS, Columbia University, New York.
HEBER DOUST CURTIS, Lick Observatory, California.
GANO DUNN, 43 Exchange Place, New York.
LAWRENCE JOSEPH HENDERSON, Harvard University, Cambridge, Mass.
REID HUNT, Harvard Medical School, Boston, Mass.
TREAT BALDWIN JOHNSON, Yale University, New Haven, Conn.
WINTHROP JOHN VANLEUVEN OSTERHOUT, Harvard University, Cambridge, Mass.
FREDERICK HANLEY SEARES, Mt. Wilson Observatory, Pasadena, Cal.
WILLIAM ALBERT SETCHELL, University of California, Berkeley, Cal.
GEORGE OWEN SQUIER, Major General U. S. A., Washington, D. C.
AUGUSTUS TROWBRIDGE, Princeton University, Princeton, N. J.
OSWALD VEBLEN, Princeton University, Princeton, N. J.
ERNEST JULIUS WILCZYNSKI, University of Chicago, Chicago, Ill.
EDWIN BIDWELL WILSON, Massachusetts Institute of Technology, Cambridge, Mass.

SCIENTIFIC SESSIONS

Two public lectures on the WILLIAM ELLERY HALE Foundation were given on April 28 and 29 by JAMES HENRY BREASTED, of the University of Chicago, on the Origin of Civilization.

Four public scientific sessions were held on April 28 and 29 at which the following papers were presented:

(NOTE: A dagger † indicates that the paper has been or shortly will be printed in these PROCEEDINGS; the numbers following the dagger are page references to this volume.)

ALFRED G. MAYOR: The age of the fringing reef of Tutuila, American Samoa.

CHARLES D. WALCOTT: Seaweeds and sponges of the Middle Cambrian.

ROBERT G. AITKEN: The spectra of the visual binary stars.

GEORGE E. HALE, F. ELLERMAN, S. B. NICHOLSON and A. H. JOY: The magnetic polarity of sun spots.

WALTER S. ADAMS and A. H. JOY: The motions in space of some stars of high radial velocity.† 239–241.

WALTER S. ADAMS and G. STRÖMBERG: The use of the spectroscopic method for determining the parallaxes of the brighter stars.† 228–232.

ADRIAAN VAN MAANEN (introduced by George E. Hale): Evidence of stream-motion afforded by the faint stars in the Orion Nebula.† 225–228.

GRAHAM LUSK and H. V. ATKINSON: The production of fat from protein after giving meat in large quantity to a dog.† 246–248.

WILLIAM S. HALSTED: End-to-end anastomosis of the intestine—experimental study.

ROBERT M. YERKES (introduced by George E. Hale): Psychological examining in the United States Army.

R. S. LULL (By title): Biographical Memoir of SAMUEL WENDELL WILLISTON.

FREDERICK H. SEARES (introduced by George E. Hale): Relation between color and luminosity for stars of the same spectral type.† 232–238.

FREDERICK H. SEARES, A. VAN MAANEN, and F. ELLERMAN (introduced by George E. Hale): Deviations of the sun's general magnetic field from that of a uniformly magnetized sphere.† 242–246.

W. W. CAMPBELL: The solar corona.

HERBERT E. GREGORY (introduced by W. M. Davis): Plans for exploration of the Pacific.

FRANCIS G. BENEDICT, W. R. MILES, and ALICE JOHNSON: The temperature of the human skin.† 218–222.

S. J. MELTZER and M. WOLLSTEIN: The influenze of degeneration of a vagus nerve upon the development of pneumonia.†

Demonstration of war research problems at the National Bureau of Standards.

EDWIN H. HALL: The effect of great pressure on the electric conductivity and thermo-electric properties of metals.

EDWIN H. HALL: Comments on the results of Bridgman's experiment.

CHARLES LANE POOR (introduced by J. S. Ames): Line of position computer.

IRVING LANGMUIR: The arrangement of electrons in atoms and molecules.† 252–259.

HENRY F. OSBORN: Palaeomastodon, the ancestor of the long-jawed mastodons only.† 265–266.

HENRY F. OSBORN: Seventeen skeletons of Moropus: probable habits of this animal.† 250–252.

THOMAS B. OSBORNE and ALFRED J. WAKEMAN: The preparation of vitamine-green proteins.

ARTHUR G. WEBSTER: Quantitative results in interior ballistics.† 259–263.

ARTHUR G. WEBSTER: Quantitative results in elastic hysteresis.

EDWIN H. HALL: Thermal conduction in metals, from the standpoint of dual electric conduction.

EDWIN H. HALL: The thermo-electric equation $P = T\,dV/dT$ once more.

A. O. LEUSCHUER and SOPHIA H. LEVY: Perturbations of minor plants discovered by James C. Watson: (104) Clymene, (106) Dione, (168) Sibylla, (175) Andromache. (By title.)

ARTHUR G. WEBSTER: The most perfect tuning fork.

ARTHUR G. WEBSTER: Angle of repose of wet sand.† 263–265.

ARTHUR G. WEBSTER (By title): On the equation of state of powder gases whose specific heats satisfy the law of Mallard and Le Chatelier.† 286–288.

C. C. TROWBRIDGE: Meteor train spectra.

EDWARD KASNER: Geometry of the wave equation.

C. G. ABBOT: Rotating projectiles from smooth-bore guns (illustrated).† 386–388.

C. G. ABBOT: Means for measuring the speed of projectiles in flight (illustrated).† 388–389.

C. G. ABBOT: Recent simultaneous measurements of the solar constant of radiation at Mount Wilson, California, and Calama, Chile (illustrated).† 383–386.

JOHN C. MERRIAM: Human remains from the Pleistocene of Rancho La Brea (illustrated).

One public session of the ACADEMY with the National Research Council was held on April 30 at which the following papers were presented:

GEORGE E. HALE: The past work and future plans of the National Research Council.

JOHN C. MERRIAM: The Division of General Relations, Section on Relations with Educational Institutions and State Committees.

R. A. MILLIKAN: The Division of Physics, Mathematics, Astronomy and Geophysics.

DAYTON C. MILLER: Pressures and velocities, internal and external, due to the discharge of large guns.

E. W. WASHBURN: The Division of Chemistry and Chemical Technology.

A. A. NOYES: Nitrate investigations.

WHITMAN CROSS: The Division of Geology and Geography.

R. G. HUSSEY: The Division of Medicine and Related Sciences.

R. M. YERKES: Psychology in relation to the war.

C. E. MCCLUNG: The Division of Agriculture, Botany, Forestry, Zoology and Fisheries.

G. H. CLEVENGER: The Division of Engineering.

AWARD OF MEDALS

The Academy assembled for dinner at the Wardman Park Inn on the evening of April 29, when medals were presented as follows:

The Agassiz Medal, for research in oceanography to Albert I, Prince of Monaco.

The Henry Draper Medal, to Charles Fabry, of the University of Marseilles, in recognition of his researches in Physics and Astronomy, chiefly by means of interferometers.

RESEARCH GRANTS FROM THE TRUST FUNDS OF THE ACADEMY

During the twelve months preceding the Annual Meeting of the Academy the following grants for the promotion of research were made from the Trust Funds of the Academy.

GRANTS FROM THE BACHE FUND

No. 210. WAYNE J. ATWELL, University of Buffalo, Medical Department, $210. For investigation on the development of the human hypophysis cerebri.

No. 211. GEORGE H. SHULL, Princeton, N. J. $360. For continuation of studies in linkage and other genetical phenomena of Oenothera, and duplication of factors, multiple allelomorphism and other genetical phenomena in Shepherd's-purse.

No. 212. ARTHUR G. WEBSTER, Clark University, Worcester, Mass., $1500. For study of the air-wave accompanying a projectile.

No. 213. DUNCAN S. JOHNSON, Johns Hopkins University. $300. For a study of the behavior and character of the chromosomes at spermatogenesis, etc., in certain tropical liverworts.

GRANTS FROM THE WATSON FUND

No. 18. JOHN A. MILLER, Sproul Observatory, $500. For the employment of assistance in measuring and reducing plates for the determination of parallaxes for the year beginning July 1, 1919. (Supplementary to Grant No. 17.)

No. 19. HERBERT C. WILSON, Goodsell Observatory, $300. For the employment of assistance in securing, measuring, and reducing photographic positions of minor planets for the year beginning July 1, 1919. (Supplementary to Grant No. 16.)

No. 20. J. A. PARKHURST, $500. For the employment of assistance in measuring and reducing plates for photographic and photovisual magnitudes in the North Polar Sequence and in the parallax field on which the Yerkes Observatory is working; the grant to be available during the year beginning June 1, 1919.

GRANTS FROM THE MARSH FUND

No. 3. ROY L. MOODIE, University of Illinois, College of Medicine, Chicago, $200. For "Studies in Paleopathology" for the purpose of contributing to the History of Medicine and attempting to determine what part, if any, disease has played in the extinction of races.